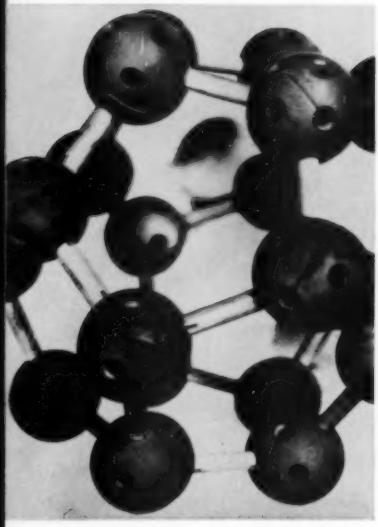
JULY 1959

Journal

VOL. 51 • NO. 7

AMERICAN WATER WORKS ASSOCIATION



AWWA's pentagon is all balled up, too, showing molecular structure of water

In this issue:

DEVELOPMENT OF RESOURCES
Leopold, Taylor

SALINE WATER CONVERSION
Koenig, Powell

SUBMERSIBLE PUMPS
Dolson

TANK REPAIR WITH PLASTICS
Erickson, Tabor

WATER SUBSTANCE
Buswell

COLLOID STABILITY
Woxholt

WATER SUPPLY AT POINT BARROW
Boyd, Boyd

OINTMENT TINS AND MEMBRANE FILTER
Noble, Reitman

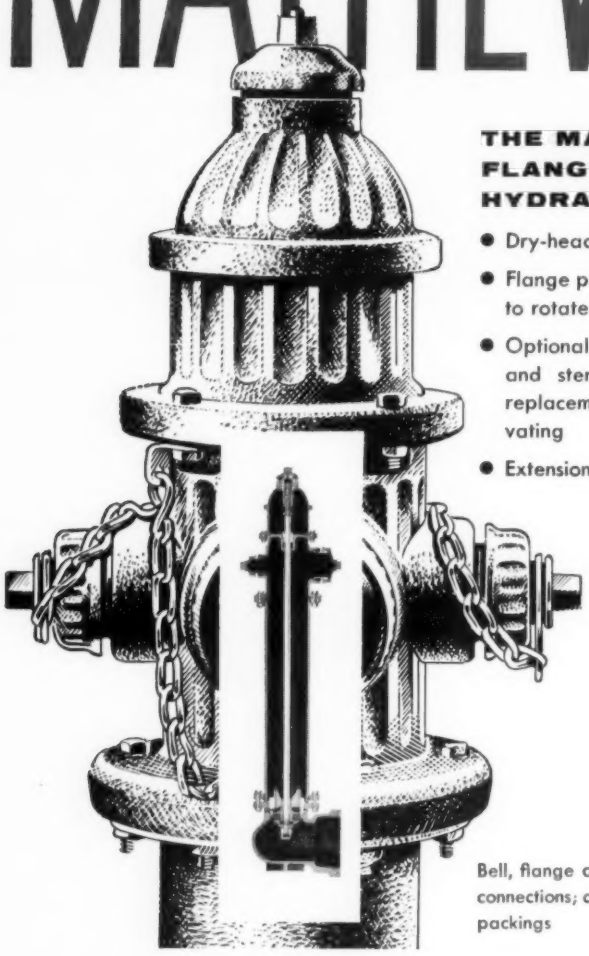
EFFECTS OF HALOGENS
Brazis, Bryant, Leslie, Woodward, Kabler

MANUAL ON WATER METERS
AWWA M6

SUGGESTED DETERMINATION METHODS
Navone, Goldman

STANDARD FOR GATE VALVES
AWWA C500

MATHEWS



THE MATHEWS FLANGE BARREL HYDRANT

- Dry-head construction
- Flange permits nozzle section to rotate 360°
- Optional breakable flange and stem coupling permits replacement without excavating
- Extension section available

Bell, flange or mechanical-joint pipe connections; conventional or "O" ring packings

R. D. WOOD COMPANY

Public Ledger Building, Independence Square • Philadelphia 5, Pa.

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

Journal

AMERICAN WATER WORKS ASSOCIATION | **July 1959**

2 PARK AVE., NEW YORK 16, N.Y. • **Phone: MUrray Hill 4-6686** | **Vol. 51 • No. 7**

Contents

Water Resource Development and Management.....LUNA B. LEOPOLD 821

Progress in the Development of Municipal Supplies.....EDWARD F. TAYLOR 828

Economic Boundaries of Saline Water Conversion.....LOUIS KOENIG 845

Discussion.....SHEPPARD T. POWELL 862

Submersible Pumps as Booster Stations in St. Louis County.....FRANK E. DOLSON 863

Storage Tank Repair With Plastics.....CLAUD R. ERICKSON 873

Discussion.....LORING E. TABOR 877

Correction—Radiological Health Training (MOELLER, PECSOK, KRAMER)..... 878

Fifty Years of Advancement in the Knowledge of Water Substance
ARTHUR M. BUSWELL 879

Electrical Conductivity and the Stability of Colloids.....WILLY G. WOXHOLT 885

Water Supply Problems at Point Barrow..WILLIAM L. BOYD & JOSEPHINE W. BOYD 890

Inhibitory Effect of Ointment Tins on Growth of Coliform Organisms in the Membrane Filter Technique.....RALPH E. NOBLE & MARVIN REITMAN 897

Effectiveness of Halogens or Halogen Compounds in Detoxifying *Clostridium botulinum* Toxins.....A. RICHARD BRAZIS, ALTON R. BRYANT, JAMES E. LESLIE, RICHARD L. WOODWARD & PAUL W. KABLER 902

Water Meters—Selection, Installation, Testing, and Maintenance—AWWA M6

Chapter 4—Meter Selection for Accurate Measurement of Various Customer Demands 913

Chapter 5—Effects of Friction and Pressure Losses on Service Adequacy..... 921

Chapter 6—Meter Installation..... 928

Suggested Titrimetric Method for Sulfate Determination.....REMO NAVONE 932

Correction—Basic Fuchsin and Sodium Sulfite (R. E. NOBLE & M. REITMAN)..... 934

Suggested Amperometric Titration Method for Sulfide Determination
EUGENE GOLDMAN 935

Reprints Available..... 936

Tentative AWWA Standard for Gate Valves for Ordinary Water Works Service
AWWA C500-59T 937

Departments

Officers and Directors..... *2 P&R*

Coming Meetings..... *8 P&R*

Percolation and Runoff..... *37, 100 P&R*

Condensation..... *64 P&R*

Employment Information..... *112 P&R*

Service Lines..... *114 P&R*

HARRY E. JORDAN, *Secretary*

R. J. FAUST, *Exec. Asst. Secy.* — ERIC F. JOHNSON, *Asst. Secy.—Publications*

LAWRENCE FARBER, *Managing Editor* — ROBERT A. NYE, *Production Manager*

ARNE E. GUBRUD, *Asst. Editor* — MILTON HOROWITZ, *Asst. Editor*

Journal AWWA is published monthly at Prince & Lemon Sts., Lancaster, Pa., by the Am. Water Works Assn., Inc., 2 Park Ave., New York 16, N.Y. Second-class postage paid at Lancaster, Pa. Authorized Aug. 6, 1918. $8.00 of members' dues are applied as a subscription to the JOURNAL; additional single copies to members—60 cents; single copies to non-members—85 cents. Indexed annually in December; and regularly by *Industrial Arts Index* and *Engineering Index*. Microfilm edition (for JOURNAL subscribers only) by University Microfilms, Ann Arbor, Mich.

© 1959, by the American Water Works Association, Inc. Made in U.S.A.

AWWA Officers and Directors

President	LAUREN W. GRAYSON	*Past-President*	LEWIS S. FINCH
Vice-President	C. F. WERTZ	*Treasurer*	WILLIAM J. ORCHARD
Ch. W.W. Practice Com.	LOUIS R. HOWSON	*Secretary*	HARRY E. JORDAN
Ch. W.W. Admin. Com.	WENDELL R. LADUE	*Exec. Asst. Secretary*	RAYMOND J. FAUST
Ch. Publication Com.	E. SHAW COLE	*Asst. Secretary-Pub.*	ERIC F. JOHNSON

Officers of the Sections

Section	*Director*	*Chairman*	*Vice-Chairman*	*Secretary-Treasurer*
Alabama-Miss.	J. L. Haley	W. P. Gearhiser	Fred Scott Jr.	Ernest Bryan
Arizona	L. O. Gardner	H. C. Bigglestone	R. E. Polenske	A. D. Cox
California	C. P. Harnish	J. C. Luthin	J. N. Spaulding	R. E. Dodson Jr.
Canadian	C. S. Anderson	G. R. Davis	J. D. Kline	A. E. Berry
Chesapeake	R. W. Haywood Jr.	A. P. Rudder	V. W. Faivre	C. J. Lauter
Cuban	L. H. Daniel	L. A. Plana	R. Garcia Montes	Juan Berasategui
Florida	F. A. Eidsness	D. B. Lee	H. T. Skaggs	J. G. Simmons
Illinois	H. H. Gerstein	Armon Lund	J. C. Vaughn	D. W. Johnson
Indiana	J. L. Ford Sr.	H. R. Wilke	J. B. Wilson	C. H. Canham
Intermountain	W. F. Richards	C. W. Wilson	R. J. Huckabee	W. C. Hague
Iowa	M. K. Tenny	P. J. Houser	R. H. Thompson	J. J. Hail
Kansas	R. H. Hess	O. K. Brandon	R. L. Chandler	H. W. Badley
Kentucky-Tenn.	J. J. Davis	—	R. L. Lawrence Jr.	J. W. Finney Jr.
Michigan	H. O. Self	L. V. Garrity	H. L. Keinath	T. L. Vander Velde
Missouri	W. B. Schworm	J. L. Tuepker Jr.	L. E. Martin	W. A. Kramer
Montana	D. S. Thomas	C. W. Brinck	E. R. Waldo	A. W. Clarkson
Nebraska	G. H. Beard	E. C. Wagner	R. E. Arraj	J. J. Rossbach Jr.
New England	K. R. Kennison	C. L. Ahlgren	A. J. Minkus	R. M. Soule
New Jersey	R. E. Bonyun	J. J. Reager	L. W. Klockner	A. F. Pleibel
New York	J. M. Diven	J. J. Meehan	C. W. Kidd	Kimball Blanchard
North Carolina	J. R. Purser Jr.	W. E. Long Jr.	R. E. Ebert	D. Y. Brannock
North Central	L. H. Coult	A. T. Hanson	C. M. Bach	L. N. Thompson
Ohio	D. D. Heffelfinger	S. D. Bresler	Pierce Bailey	J. H. Bass
Pacific Northwest	W. H. Berkeley	J. L. Geren	A. H. Perry	F. D. Jones
Pennsylvania	S. S. Baxter	K. E. Shull	H. E. Beckwith	L. S. Morgan
Rocky Mountain	J. O. Jones	Ray Nixon	J. M. Hunter	V. A. Vaseen
Southeastern	C. C. Lanford	L. R. Simonton	O. M. Fuller	N. M. deJarnette
Southwest	K. F. Hoefle	R. L. Lawrence	H. J. Graeser	L. A. Jackson
Virginia	W. B. Harman	S. M. Hodges	Brent Remsburg	E. H. Ruehl
West Virginia	D. H. Clark	J. B. Douglass	H. K. Gidley	H. W. Hetzer
Wisconsin	O. J. Muegge	A. J. Jark	Philip Davy	Harry Breimeister

Directors Representing the Water and Sewage Works Manufacturers Assn.

J. A. Frank H. S. Howe R. V. Ford

Officers of the Divisions

Division	*Chairman*	*Vice-Chairman*	*Secretary*
Water Distribution	J. B. Ramsey	B. E. Payne	H. J. Graeser Jr.
Water Purification	J. M. Jester	C. A. Black	H. E. Hudson Jr.
Water Resources	J. W. Cramer	A. R. Davis	R. W. Morse
Water Works Management	W. D. Hurst	W. R. Seeger	Gerald Remus

Making a 6" outlet under pressure in a 20" Lock Joint Prestressed Concrete Cylinder Pipe.

Tapping a 1" house connection under pressure in Lock Joint Concrete Pressure Pipe.

TAPPING LOCK JOINT CONCRETE PRESSURE PIPE

Simple . . . Efficient . . . Time-tested
Thousands of field installations have proved the ease and efficiency with which LOCK JOINT CONCRETE PRESSURE PIPE can be tapped under pressure. Service connections as well as larger outlets up to 36" in diameter can be made without interruption of service or damage to the line.

In addition to safe, easy tapping of all diameters, LOCK JOINT CONCRETE PRESSURE PIPE also combines long life, dependability, permanent high carrying capacity, ease of installation, and negligible maintenance. These features make it the logical choice for distribution piping as well as water transmission lines.

LOCK JOINT PIPE CO.
East Orange, New Jersey

Sales Offices: Chicago, Ill. • Columbia, S. C. • Denver, Col. • Detroit, Mich. • Hartford, Conn. • Kansas City, Mo. • Perryman, Md.
Pressure • Water • Sewer • REINFORCED CONCRETE PIPE • Culvert • Subaqueous

LIST OF ADVERTISERS

	P&R PAGE
Alabama Pipe Co.	48
Allied Chemical Corp., General Chemical Div.	—
Allied Chemical Corp., Plastics & Coal Chemicals Div.	—
Allis-Chalmers Mfg. Co.	119
Allis-Chalmers Mfg. Co., Hydraulic Div.	—
American Agricultural Chemical Co.	70
American Brass Co., The	89
American Cast Iron Pipe Co.	99
American Concrete Pressure Pipe Assn.	16, 17
American Cyanamid Co., Process Chemicals Dept.	22
American Pipe & Construction Co.	51
American Well Works	—
Anthracite Equipment Corp.	—
Aqua Survey & Instrument Co.	104
Armco Drainage & Metal Products, Inc.	30
Atlas Asbestos Co. Ltd.	—
Badger Meter Mfg. Co.	—
Bethlehem Steel Co.	24
B-I-F Industries, Inc.	5
Buffalo Meter Co	—
Burgess-Manning Co., Penn Instruments Div.	—
Byron Jackson Pumps, Inc.	—
Calgon Co.	113
Calmet Meter Div., Worthington Corp.	95
Carborundum Co., The	—
Carus Chemical Co.	—
Cast Iron Pipe Research Assn., The	108, 109
Centriline Corp.	—
Chain Belt Co.	—
Chapman Valve Mfg. Co.	—
Chemical Process Co.	—
Chicago Bridge & Iron Co.	—
Clow, James B., & Sons	9, 76, 77
Cochrane Corp.	—
Combination Pump Valve Co.	107
Darley, W. S., & Co.	116
Darling Valve & Mfg. Co.	—
De Laval Steam Turbine Co.	105
DeZurik Corp.	—
Dicalite Div.	—
Dorr-Oliver Inc.	Cover 3
Dresser Mfg. Div.	27
Eddy Valve Co.	9, 76, 77
Electro Rust-Proofing Corp.	—
Ellis & Ford Mfg. Co.	—
Emhart Mfg. Co., Maxim Div.	—
Fairchild Aerial Surveys, Inc.	49
Fiese & Firstenberger	—
Filtration Equipment	84
Ford Meter Box Co., The	18
Foster Engineering Co.	—
Foxboro Co.	15
Gamon Meter Div., Worthington Corp.	79
General Chemical Div., Allied Chemical Corp.	—
General Filter Co.	91
Glenfield & Kennedy	—
Golden-Anderson Valve Specialty Co.	101
Graver Tank & Mfg. Co.	67
Graver Water Conditioning Co.	—
Greenberg's, M., Sons	—
Griffin Wheel Co.	—
Hagan Chemicals & Controls, Inc.	—
Halliburton Oil Well Cementing Co.	—
Hammond Iron Works	—
Harco Corp.	74
Hays Mfg. Co.	92
Hersey Mfg. Co.	47
Hungerford & Terry, Inc.	96
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co.	35
Inertol Co., Inc.	—
Infilco Inc.	39
International Salt Co., Inc.	75
Iowa Valve Co.	9, 76, 77
Johns-Manville Corp.	6, 7
Jones Chemicals, Inc.	87
Keasbey & Mattison Co.	—
Kennedy Valve Mfg. Co., The	—
Klett Mfg. Co.	80
Koppers Co., Inc.	69
Kruger, Harold, Instruments	—
LaMotte Chemical Products Co.	—
Layne & Bowler, Inc.	71
Leadite Co., The	Cover 4
Leopold, F. B., Co.	97
Lock Joint Pipe Co.	3
Ludlow Valve Mfg. Co.	—
M & H Valve & Fittings Co.	14
Millipore Filter Corp.	—
Monterey Sand Co.	54
Morgan Steel Products, Inc.	123
Mueller Co.	65
Nalco Chemical Co.	25
National Water Main Cleaning Co.	53
Neptune Meter Co.	36
Northern Gravel Co.	81
Olin Mathieson Chemical Corp.	103
Orangeburg Mfg. Co.	55
Peerless Pump Div.	—
Pelton Div., Baldwin-Lima-Hamilton	73
Permutit Co.	44, 45
Philadelphia Quartz Co.	90
Photovolt Corp.	26
Pilot Mfg. Co.	—
Pittsburgh-Des Moines Steel Co.	41
Pittsburgh Equitable Meter Div. (Rockwell Mfg. Co.)	124
Plastics & Coal Chemicals Div., Allied Chemical Corp.	—
Pollard, Jos. G., Co., Inc.	111
Portland Cement Assn.	—
Pratt, Henry, Co.	43
Precision Chemical Pump Corp.	—
Preload Co., Inc	—
Reilly Tar & Chemical Corp.	—
Roberts Filter Mfg. Co.	19
Rockwell Mfg. Co.	124
Rockwell, W. S., Co.	115
Rohm & Haas Co.	—
Ronald Press Co.	—
Ross Valve Mfg. Co.	31
Servicised Products Corp.	—
Shawnee Mfg. Co.	—
Shell Chemical Corp.	28, 29
Simplex Valve & Meter Co.	23
Smith, A. P., Mfg. Co., The	121
Southern Pipe Div. of U.S. Industries	117
Sparling Meter Co.	—
Steel Plate Fabricators Assn.	83, 93
Stuart Corp.	116
Taylor Iron Works	86
Tennessee Corp.	72
Trinity Valley Iron & Steel Co.	—
U.S. Pipe & Foundry Co.	20, 21
Upson Co.	—
Vulcan Materials Co.	85
Wachs, E. H., Co.	—
Walker Process Equipment, Inc.	63
Wallace & Tiernan Inc.	32
Wheeler, C. H., Mfg. Co.	—
Wilbur & Williams Co., Inc., The	11
Wiley, John, & Sons, Inc.	—
Wood, R. D., Co.	Cover 2
Woodward Iron Co.	—
Worthington Corp	12, 13

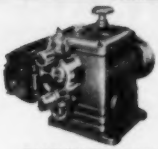
Directory of Professional Services—pp. *56-62 P&R*

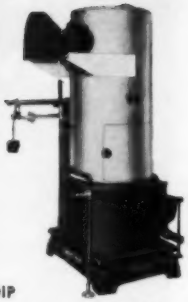
Do You Feed ALUM?

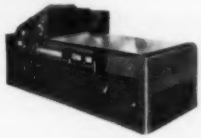
Liquid? Dry? By Weight? By Volume?

LOSS-IN-WEIGHT

DISC


DIAPHRAGM PUMP


UNIVERSAL


GRAVIMETRIC

ROTODIP

Omega offers the most complete line of ALUM FEEDERS . . . backed by a wealth of practical experience and equipment knowledge to help you get the right feeder for your specific requirements. Where desired, Omega is ready to supply auxiliary equipment and instrumentation: totalizers, master control panels, remote controls, proportional pacing systems, alarms, batch counters, and other related units.

CLASS OF FEEDER	FEEDS ALUM—	FEEDING PRINCIPLE	SIZES	ACCURACY	CAPACITIES		RANGES
					MIN.	MAX.	WITHOUT CHANGE GEARS
Model 30 Loss-in-Weight	DRY	GRAVIMETRIC	3	± 1% by weight	10#/hr.	4000#/hr.	100:1
Model 50-8 Belt	DRY	GRAVIMETRIC	1	± 1% by weight	100#/hr.	3000#/hr.	100:1
Model 37-20 Belt	DRY	GRAVIMETRIC	1	± 1% by weight	500#/hr.	2000#/hr.	100:1
Model 50A Disc	DRY	VOLUMETRIC	1	± 3% by weight	40 cu. in./hr.	800 cu. in./hr.	20:1
Model 51 Disc	DRY	VOLUMETRIC	1	± 3% by weight	40 cu. in./hr.	6 cu. ft./hr.	100:1
Model 20 Universal	DRY	VOLUMETRIC	3	± 3% by weight	30 cu. in./hr.	85 cu. ft./hr.	40:1
Model 32 Loss-in-Weight	LIQUID	GRAVIMETRIC	3	± ½% by weight	5#/hr.	60,000#/hr.	25:1
Model 65 Rotodip	LIQUID	VOLUMETRIC	1	± 1%	5 GPH	1800 GPH	100:1
Model 47 Chem-O-Feeder	LIQUID	VOLUMETRIC	3	± 1% by weight	0.2 GPH	49 GPH	

For Bulletins describing any of the Feeder classes listed in the table, write **B-I-F Industries, Inc., Dept. U., 365 Harris Ave., Prov. 1, R. I.**

B-I-F

B-I-F INDUSTRIES

BUILDERS-PROVIDENCE • PROPORTIONEERS • OMEGA

DIRECTLY SUPPORTING THE INDUSTRY'S ADVANCEMENT PROGRAM

Johns-Manville brings you an entirely new concept of evaluating your community's needs . . .

NEW! **84-page book tells you how to get better water service for your**

Gives unique step-by-step method for water service evaluation and trouble-spotting.

Uses case histories to show how improved water service can benefit your community.

Tells how to make your community want—and approve—water system improvements.

"PRICELESS WATER . . . it's your business" is written expressly for water utility managers, engineers, public officials—all those business and community leaders who are alert to the basic contribution good water makes to the life and economic well-being of a community.

The result of months of study, planning and research—"PRICELESS WATER" is edited in four sections:

Section One, **"How good water service benefits your community,"** gives you needed "ammunition" to convince the most skeptical of the many advantages of good water service. It shows how improved water service affects property values and insurance rates. How an efficient water system will attract business. How a poor system turns it away! This section tells how entire communities have benefited by water improvements.

Section Two, **"How to evaluate your water system,"** is edited for water and town planning officials. It is a new, step-by-step method for water service evaluation. It shows how you can quickly and easily evaluate the efficiency of everything from community water supply, treatment and distribution to metering, staff facilities and operations.

Section Three, **"How to turn evaluation into improved water service,"** tells when a preliminary engineering survey is needed.

community!

When and how to retain a consulting engineer. How to use his report as a springboard for action. Fiscal agents, and when and how to use them. Also contains a helpful explanation of various financing methods.

Section Four, **"Arousing the public to action,"** is an easy-to-follow, success-proven handbook on public relations. It tells how a soundly conceived PR program can sell your community on water service.

In short, "PRICELESS WATER" is the hard-hitting tool you need to get your community the improved water service it needs. Send the coupon for your free copy, now!

JOHNS-MANVILLE

BOX 14, NEW YORK 16, N.Y.

Please send me without obligation a copy of the new 84-page water advancement brochure "PRICELESS WATER . . . it's your business."

Name_____ Title_____

Address_____

City_____ Zone____ State_____

Coming Meetings

AWWA SECTIONS

Sep. 8–10—Rocky Mountain Section, at Jackson Lake Lodge, Moran, Wyo. Secretary, V. A. Vaseen, 833—23rd St., Denver 2, Colo.

Sep. 9–11—Canadian Section, Maritime Branch, at White Point Beach Lodge, Liverpool, N.S. Secretary, J. D. Kline, Gen. Mgr., Public Service Com., Halifax, N.S.

Sep. 9–11—Wisconsin Section, at Hotel Schroeder, Milwaukee. Secretary, Harry Breimeister, Chief Utilities Engr., City Engineer's Office, City Hall, Milwaukee.

Sep. 14–16—Kentucky-Tennessee Section, at Lafayette Hotel, Lexington, Ky. Secretary, J. Wiley Finney Jr., Howard K. Bell, Cons. Engrs., 553 S. Limestone St., Lexington, Ky.

Sep. 16–18—New York Section, at Saranac Inn, Upper Saranac Lake. Secretary, Kimball Blanchard, Neptune Meter Co., New York Branch Sales Office, 2222 Jackson Ave., Long Island City.

Sep. 16–18—North Central Section, at Pick-Nicollet Hotel, Minneapolis, Minn. Secretary, L. N. Thompson, Gen. Mgr., Water Dept., St. Paul 2, Minn.

Sep. 23–25—Michigan Section, at Bancroft Hotel, Saginaw. Secretary, T. L. Vander Velde, Chief, Section of Water Supply, State Dept. of Health, DeWitt Rd., Lansing.

Sep. 27–29—Missouri Section, at President Hotel, Kansas City. Secretary, Warren A. Kramer, Chief, Water Supply, Div. of Health, State Office Building, Jefferson City.

Oct. 7–9—Chesapeake Section at Sheraton-Belvedere Hotel, Baltimore, Md. Secretary, Carl J. Lauter, 6955—33rd St., N.W., Washington, D.C.

Oct. 8–9—Intermountain Section, Pocatello, Idaho. Secretary, W. C. Hague, Chief Engr., Metropolitan Water Dist., 703 Tribune Bldg., Salt Lake City, Utah.

Oct. 14–16—Iowa Section, at Fort Des Moines Hotel, Des Moines. Secretary, J. J. Hail, Supt., Water Dept., City Hall, Dubuque.

Oct. 18–21—Alabama-Mississippi Section (with Southwest Section) at Roosevelt Hotel, New Orleans, La. Secretary, Ernest Bryan, Southern Sales Mgr., McWane Cast Iron Pipe Co., Box 2601, Birmingham, Ala.

Oct. 18–21—Southwest Section (with Alabama-Mississippi Section) at Roosevelt Hotel, New Orleans, La. Secretary, L. A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 22–24—New Jersey Section, at Hotel Madison, Atlantic City. Secretary, A. F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

(*Continued on page 10 P&R*)

There's always something new at

IOWA

THE *New* LOOK

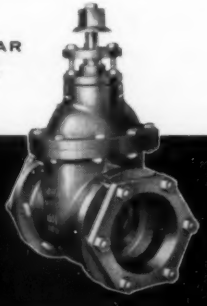
As it has for 50 years, IOWA Valve Company is continually improving its products and facilities.

These improvements consist of new and better materials, more modern production methods, and improved product designs.

The latest design change provides fluting around hydrant cover bolts which make it easier to unbolt. This not only simplifies repair and maintenance but adds a neat, attractive, streamlined appearance.

The new IOWA hydrants give the same dependable performance and proved economy for which IOWA products are famous. When valves and hydrants enter your plans, be sure you have the most up-to-date information on IOWA products.

OUR 50th YEAR
1909 • 1959



IOWA VALVE COMPANY
Oskaloosa, Iowa
A subsidiary of James B. Clow & Sons, Inc.

Coming Meetings

(Continued from page 8 P&R)

Oct. 28–29—West Virginia Section, at Chancellor Hotel, Parkersburg. Secretary, Hugh W. Hetzer, Engr., Union Carbide Chemical Co., Box 8361, South Charleston.

Oct. 28–30—Ohio Section, at Biltmore Hotel, Dayton. Secretary, J. Howard Bass, Robt. F. McGivern & Assocs., 1771 W. 5th Ave., Columbus.

Oct. 30—California Section (Business Meeting) at Hacienda Hotel, Bakersfield. Secretary, Roy E. Dodson Jr., Supt. of Production, San Diego Water Dept., Balboa Park, San Diego.

Nov. 4–6—Virginia Section, at Hotel Roanoke, Roanoke. Secretary, E. H. Ruehl, R. Stuart Royer & Assocs., 15 W. Cary St., Richmond.

Nov. 9–11—North Carolina Section, at Washington Duke Hotel, Durham. Secretary, D. Y. Brannock, Director, Utilities Dept., Burlington.

Nov. 15–19—Florida Section, at Hillsboro Hotel, Tampa. Secretary, J. G. Simmons, Plant Supt., West Palm Beach Water Dept., Box 1311, West Palm Beach.

Dec. 3–5—Cuban Section, Havana. Secretary, Juan Berasategui, Civ. Engr., Calle K, No. 303, Apdo. 22, Vedado, Havana.

OTHER ORGANIZATIONS

Jul. 20–Aug. 14—USPHS Summer Training Institute short courses, to be given at Western Massachusetts Public Health Center on campus of University of Massachusetts, Amherst, Mass.: Jul. 20–31—Basic Radiological Health; Jul. 27–Aug. 7—Aquatic Biology for Engineers; Aug. 10–14—Bioassay & Pollution Ecology. Write: Sylvan C. Martin, Regional Engr., Region II, Rm. 1200, 42 Broadway, New York 4, N.Y.

Jul. 22–25—International Conference on Waste Disposal in Marine Environment, under multiple sponsorship, University of California, Berkeley, Calif. Write: Dept. of Conferences, University Extension, Univ. of California, Berkeley 4, Calif.

Aug. 17–21—Short course on "Recent Developments in Water Bacteriology," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Sep. 7–11—Ion-Exchange Conference, sponsored by Oak Ridge National Lab., at Gatlinburg, Tenn. (attendance limited). Write: Prof. William Rieman III, Vice-Chairman, Ion-Exchange Conference, R. G. Wright Lab., Rutgers State University, New Brunswick, N.J.

Sep. 13–18—American Chemical Society, Atlantic City, N.J.

Sep. 21–25—Instrument-Automation Conference & Exhibit, Instrument Society of America, International Amphitheater, Chicago, Ill. Write: H. S. Kindler, Director of Tech. & Educational Services, 313—6th Ave., Pittsburgh 22, Pa.

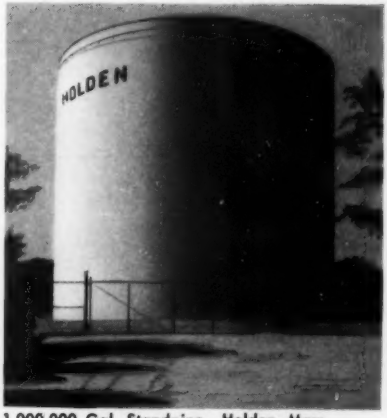
Sep. 28–Oct. 1—American Welding Society, Sheraton-Cadillac Hotel, Detroit, Mich.

Oct. 12–15—Federation of Sewage & Industrial Wastes Assns., Statler Hilton Hotel, Dallas, Tex.

KING
PAINT MAKERS SINCE 1834

SPECIALISTS and PIONEERS IN COATINGS SYSTEMS for POTABLE WATER STORAGE UNITS

400,000 Gal. Elevated Tank Newton, Mass.



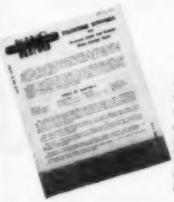
1,000,000 Gal. Standpipe , Holden, Mass.

INSIDE and OUT . . . protected from rust, corrosion and odor by KING TANK COATINGS SYSTEMS Whether in fabrication, initial painting, or field repainting, KING TANK COATINGS SYSTEMS are specifically formulated with these exclusive proven advantages:

1. **Non-toxicity**
2. **No Taste Impartment**
3. **Corrosion Prevention**
4. **Maximum Durability**

TRIPLE LEADKOTE or ZDO-120

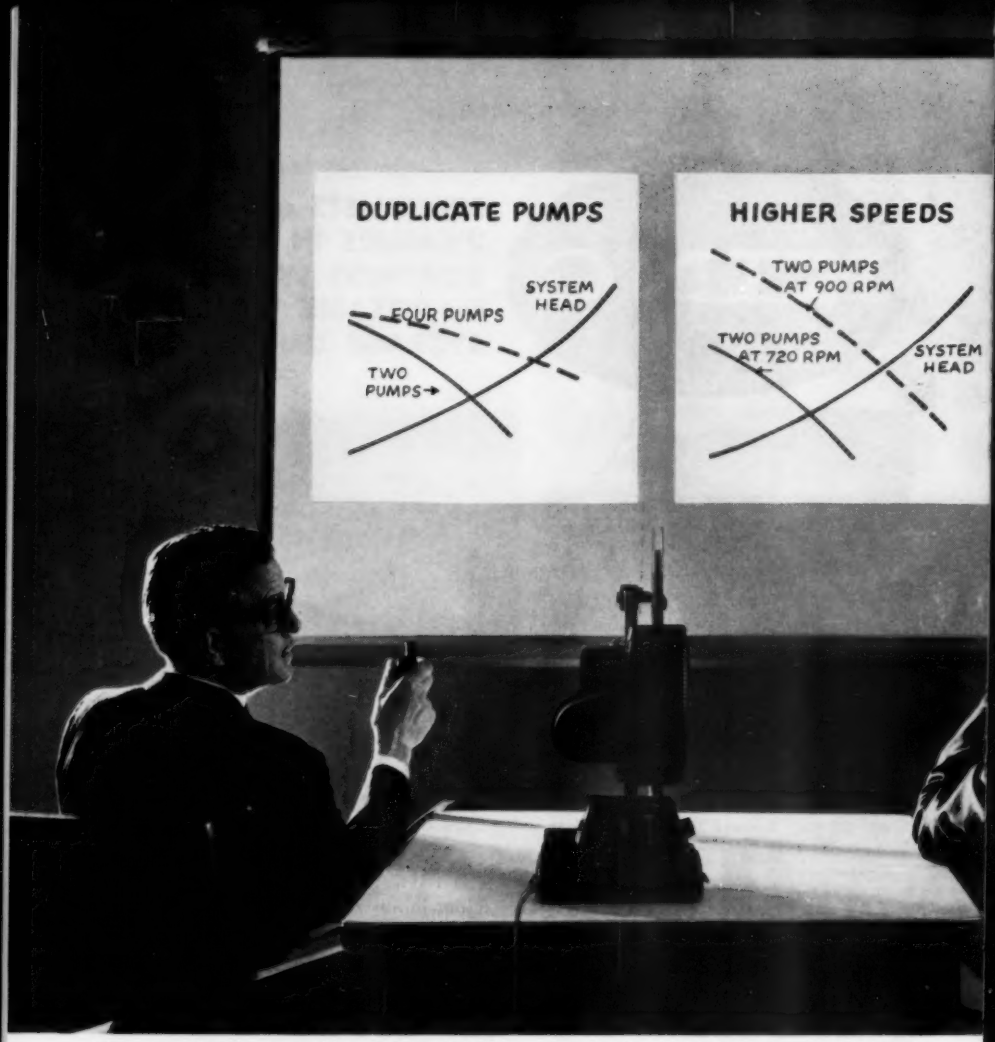
systems for painting interiors of potable water tanks and standpipes offer defense in depth against corrosion, defense in formulation against improper application. See why some 80% of the Municipal water storage tanks in New England alone are protected with KING TANK COATINGS.



Send for Bulletin 57070, a comprehensive 7 page booklet giving full analytical and application specifications on KING TANK COATINGS SYSTEMS. This is not a sales brochure, but a strictly technical work.

KING DIVISION **THE WILBUR & WILLIAMS CO., INC.**

FACTORY AND GENERAL OFFICES
660 Pleasant St., Norwood, Mass.



Two ways of taking care of future demands for increased capacity are shown here. The chart on the left indicates the performance of 4 pumps operating in parallel. The chart on the right indicates the same conditions obtained with the use of 2 pumps operating at higher speeds.

DUPLICATE PUMPS OR HIGHER SPEEDS?

A discussion of the economics of multi-speed pumps for water works

WATER WORKS REPORT
from Worthington

Today, most engineers plan for expansion by providing space for duplicate pumps, or pumps that will operate in parallel giving increased capacity as water demand increases.

Another way of taking care of increased capacity is through the use of higher speeds. By providing for multi-speed operation in the future, it may be possible to save thousands of dollars. Spare parts, as well as maintenance costs, can also be reduced.

The charts above show how this can be done. Suppose your water works now uses two 60 hp centrifugal pumps. Sometime in the future you plan to increase capacity by one-third by adding two more pumps which will operate in parallel. The total cost of the four pumps and motors installed would be approximately $26,000.

This same increase in capacity, in some instances, can be accomplished by multi-speed pumping. If you initially made the proper provisions, you could later increase the speed of the two pumps from 720 rpm to 900 rpm. This would give you the necessary capacity increase of 33⅓%. And the total cost would be only $21,000, a saving of $5,000 or approximately 20%.*

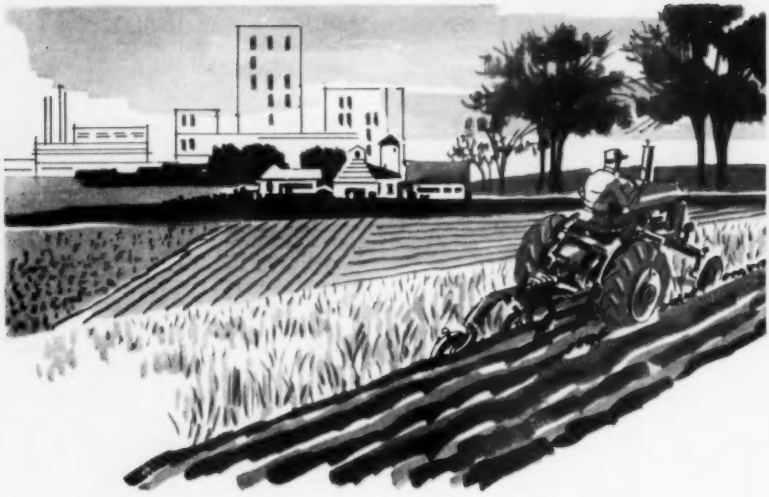
It's not necessary to limit your thinking to two-speed operation. Possibly the most economic proposal for your system would be three or four-speed operation. All public water-supply systems are different and pumping equipment is affected by different capacities, suction conditions, and static and friction heads. Therefore, all factors must be known before deciding on the proper approach. This sort of planning, however, combined with the use of multi-speed pumping when appropriate, can save you large amounts of money.

Ask your consulting engineer about the merits of multi-speed pumping. He'll explain to you its many advantages. And for unbiased equipment recommendations, get in touch with Worthington. Worthington makes all types of pumps and drives and a complete line of engines, compressors, and auxiliary equipment.

For a reprint of an engineering discussion of multi-speed pumping for water works, write to Worthington Corp., Section 105-4, Harrison, N. J. In Canada: Worthington (Canada) Ltd., Brantford, Ont.

*Cost figures are estimated and conservative. No cost has been added for additional space required by the extra pumps.

WORTHINGTON



TREES AND WATER

Strange as it may seem, there are some disadvantages to civilization. Two of them are water pollution and ground water shortage.

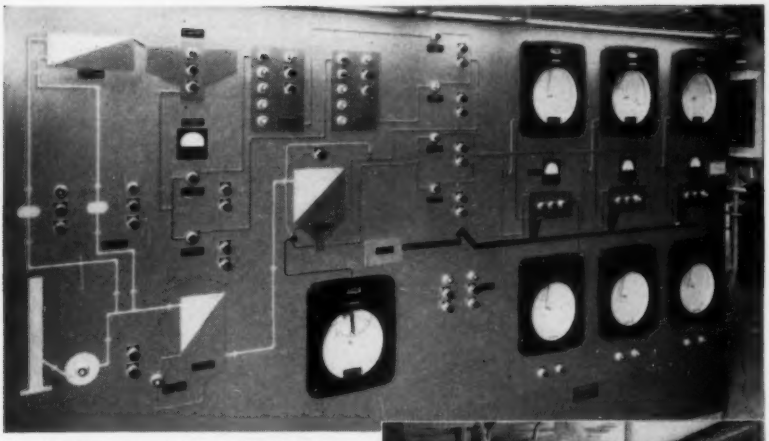
The more people in a community, obviously the more serious the water pollution prospects become, due to both domestic and industrial waste materials. Also as populations grow, forest areas tend to decrease. Growing cities, new and bigger industries, more and larger farms mean less forested area and less trees, faster rainfall runoff and less ground water storage. Trees and underbrush are Nature's way of helping rainfall soak into the ground instead of running off into streams, rivers, and the sea.

Apparently Mother Nature and the Human Race need to make some adjustments in order to satisfy each other. Ground water shortage is one of the big problems facing the American water works industry, and emphasizes the fact that the job of water works superintendent is vitally important to the American way of life. Give your water works superintendent a hand—whenever you can.

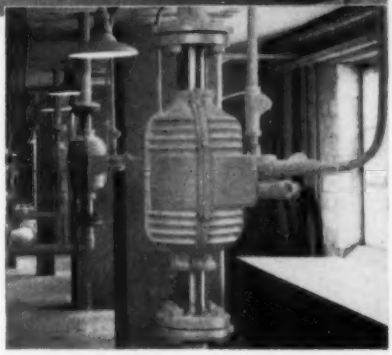
This Series is an attempt to put into words some appreciation of the water works men of the United States.

M&H VALVE
AND FITTINGS COMPANY
ANNISTON, ALABAMA

SUBSIDIARY OF WALWORTH



Graphic control panel in Feed End Building of the $1,330,000 Dayton, Ohio Lime Recalcining Plant. *Consulting Engineers: Black & Associates, Gainesville, Florida.*



Three Foxboro Magnetic Flow Meters give continuous, accurate measurement for exact control and recording of sludge flow rate to centrifuges.

at City of Dayton–

self-amortizing lime recovery plant designed around Foxboro Magnetic Meters

Installed to recover lime used in softening city water, Dayton, Ohio's million-dollar Lime Recalcining Plant actually recovers up to 20% more lime than originally added; with additional capacity to process previous sludge accumulation. Capable of recovering 150 tons of lime per day, it is expected to amortize its original cost in 20 years — and pay a substantial surplus, too.

Dayton's efficient recalcining plant was designed around Foxboro Magnetic Flow Meters — which have no flow restrictions, and easily handle sludge that soon would foul-up conventional head-loss devices. They have no pressure taps or moving parts to foul . . . need no seals or purges. Maintenance is practically nil. Rate of flow to centrifuges can be controlled exactly.

For either "difficult" or "simple" liquids, Foxboro Magnetic Flow Meters are a sound investment. Ask your Foxboro Field Engineer, or write for Bulletin 20-14C. **The Foxboro Company, 167 Norfolk Street, Foxboro, Massachusetts.**

FOXBORO
REG. U.S. PAT. OFF.

MAGNETIC
FLOW METERS

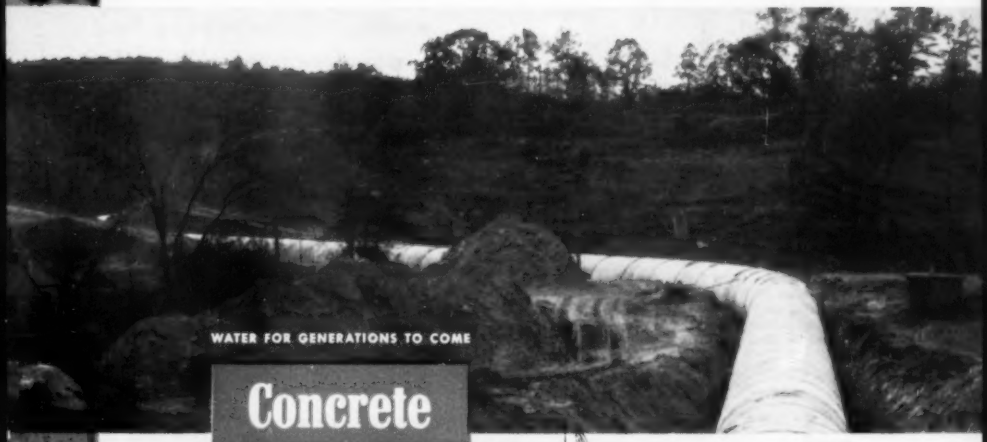
Across the Town...
or Across Country

IT'S CONCRETE CYLINDER PRESSURE PIPE FOR MAINTENANCE-FREE WATER SYSTEMS

And pipelines requiring negligible maintenance mean money in the bank for your community. Whether repairs or replacements must be made on a remote supply line or a distribution line in the middle of town, heavy expenditure is involved.

Cut these expenses to the bone by using CONCRETE CYLINDER PRESSURE PIPE, whose unexcelled performance record is a product of the strength of steel joined with the durability of concrete.

Further, this pipe is low in first cost, economical to install, easy to tap under pressure, and will retain its initial high carrying capacity throughout its exceptionally long, trouble-free life. Call on your nearest supplier of Concrete Cylinder Pressure Pipe for the utmost in dependable, economical pipelines.



WATER FOR GENERATIONS TO COME

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 N. LA SALLE STREET • CHICAGO 1, ILLINOIS

a few plain words about...

WATER METERS!

METER YOKES

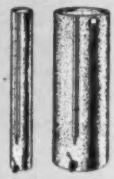
The Ford Yoke dates back to 1911. Its outstanding success resulted in a wide variety of meter holding devices called yokes. But the Ford yoke as now made offers advantages not obtainable in any other type of meter setting. Millions are in use.

LIFTER WORM LOCK

The original Ford Worm Lock was introduced almost forty years ago. Because of its simplicity, safety and powerful screw-jack action it is now widely used. The Lifter feature, a recent improvement, provides automatic attachment of the key on unlocking.

CALIBRATED TESTING TANKS

Before Ford Calibrated Testing Tanks were put on the market about 35 years ago, such meters as were tested were checked against gravimetric scales, which were complicated and inconvenient. Thousands of Ford Tanks are in service, in sizes from one to 1000 gallons.



METER VALVE

The Meter Valve is a close-coupled combination of an inverted key valve and a meter connection. It saves material, pipe joints and space in the meter setting. Ford Meter Valves bear the trademark name of Ringstyle Valves.

THE KORNERHORN

In a vertical basement pipe, against the wall or in a corner, the Kornerhorn makes a most satisfactory meter setting. Installation is fast and economical as pipe threading is eliminated. Send for detailed information.

Meters can *earn* real money. In most water utilities they measure and determine *all* the income.

It is good business to accord meters the treatment they deserve as valuable equipment and as sources of revenue. Such enlightened treatment includes settings which provide protection, easy availability for reading, and trouble-free meter changes for proper maintenance.

For 60 years our company has served thousands of water utilities in providing better water meter settings. Submit *your* problems to Ford.

THE FORD METER BOX COMPANY, INC.

FOR BETTER WATER SERVICES

WABASH, INDIANA

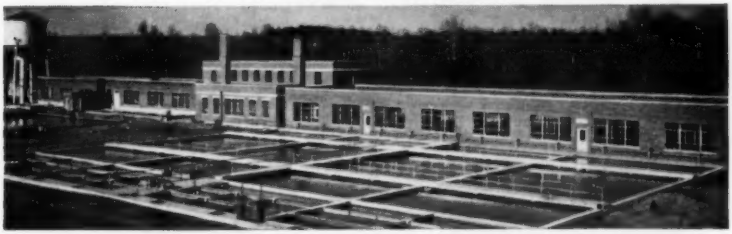
FORD

Roberts Filter Manufacturing Co.

DARBY, PENNSYLVANIA

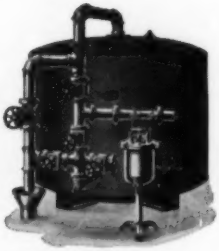
WATER PURIFICATION EQUIPMENT
STANDARD OF QUALITY FOR MORE THAN 60 YEARS

WATER FILTRATION PLANTS and EQUIPMENT
GRAVITY FILTERS and EQUIPMENT—PRESSURE FILTERS (Vertical & Horizontal)—WATER SOFTENING EQUIPMENT
SWIMMING POOL EQUIPMENT



This 8 million gallon a day water treatment plant is typical of the many hundreds of Roberts-equipped installations throughout the United States, Canada and Latin America. We welcome the opportunity to cooperate with engineers on all types of water filtration equipment projects.

- **Dependability**
- **Experience**
- **Engineering Cooperation and Service**



Roberts Style L
Vertical Pressure Filter

SWIMMING POOL EQUIPMENT

This modern pool at Levittown, Pa., built by Levitt and Sons, Inc., is representative of the thousands of Roberts-equipped swimming pools. We produce a complete line of swimming pool recirculating plants and filtration equipment, backed by more than 60 years experience in the field of water purification.

DANGEROUS WATER. Not long ago, faulty sewage disposal too often contaminated lakes and rivers... made them unfit for bathing, drinking or fishing.

MODERN SEWERAGE SYSTEMS, in which cast iron pipe and fittings are used, play a major role in keeping America's water clean, pure and wholesome... safe for bathing and drinking.

U.S. PIPE

FOR WATER, SEWERAGE AND
U. S. PIPE AND FOUNDRY COMPANY

but better than ever today!

Exacting quality checks from mine to main assure U. S. Pipe dependability

With leadership goes responsibility . . .

Cast iron pipe, for example, long recognized as America's basic water carrier, must be dependable and long-lived.

U. S. Pipe makes sure it is. By constantly checking and rechecking its pipe from start to finish . . . from mining to final casting.

The water officials who do such fine work planning and protecting the nation's water supply can be sure of this:

In U. S. cast iron pipe they have a fine ally to work with.

COKE, being discharged on coke wharf, has been made in our modern ovens from carefully blended mixture of coals obtained from U.S. Pipe mines.

HOT PIPE is inspected and weighed before entering the heat treating furnace. Each length of U. S. Pipe is subjected to temperatures automatically controlled for uniformity.

THE SPECTROGRAPH is used by U. S. Pipe to make timely and accurate chemical determinations . . . one of many quality checks that assure top performance of U. S. Pipe.

NDUSTRIAL SERVICE CAST IRON

irmingham 2, Ala. *A wholly integrated producer from mines and blast furnaces to finished pipe.*

Alum

. . . AS YOU WANT IT FROM

Cyanamid

DRY—conforming fully to A.W.W.A. standards in ground, rice, lump or powdered grades, bagged or bulk.

LIQUID—for cleaner, easier, more economical operation—in tank wagons and tank cars; from nine shipping points.

THINKING OF CONVERTING TO LIQUID?

Your costs—and savings—can be quickly and realistically determined by a Cyanamid staff with years of conversion experience behind them. For product or technical service of any kind, call Cyanamid. You'll like the results!

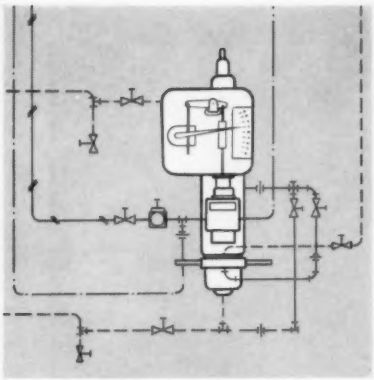
CYANAMID

AMERICAN CYANAMID COMPANY
Process Chemicals Department
30 Rockefeller Plaza, New York 20, New York

In Canada: Cyanamid of Canada Limited, Montreal and Toronto

FLUIDICS

is a Pfaudler Permutit program providing a modern, imaginative approach — plus the specialized materials and equipment — for handling and processing and controlling more profitably the liquids and gases which are the lifeblood of our manufacturing economy.



FLUIDICS AT WORK

New pneumatic transmission system more accurate, more dependable

The diagram shows a typical setup for the new Simplex system for transmitting rate of flow and loss of head to a receiver.

Rate of Flow

The new Type PN transmitter combines the exceptional accuracy and range of a differential converter operated by a mercury float with the traditional dependability of pneumatic transmission.

The transmitter consists of a differential converter which extracts the square root flow function from a primary and then positions a pneumatic motion transmitter. The transmitter produces a pneumatic 3 to 15 psig linear signal. A booster pitot diaphragm in the motion transmitter insures a low lag coefficient and fast transmission.

Besides getting a linear signal without using supplementary pneumatic relays, this new unit gives you point accuracy over wide ranges of flow with minimum differentials. The booster permits accurate transmission over long distances with minimum lag.

Loss of Head

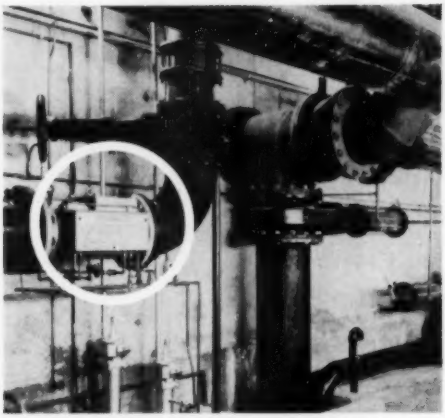
A Type TD transmitter gives accurate readings to within ±1%. It uses no stuffing boxes or relay valves, so both installation and maintenance are simple and economical.

Connected to Simplex Pneumatic Gauges, this new system should give long years of accurate, dependable, trouble-free service.

SIMPLEX®

a division of PFAUDLER PERMUTIT INC.

Specialists in FLUIDICS . . . the science of fluid processes



FLUIDICS AT WORK

Modulair Flow Controller installs as easily as a piece of pipe

So simple is this new pneumatic rate-of-flow controller, you can install it in about the time it takes to install a piece of pipe.

The differential producer and the modulator lie in a single housing. The actuator is entirely enclosed in a case which mounts directly on the housing.

Result: No complicated piping or drain system to install and maintain.

For a bulletin giving complete specs and performance data, write to our Simplex Division, Lancaster, Pennsylvania. Ask for Bulletin 951.

Fast, dependable delivery insured by new plant

This is the new $2,000,000 home of our Simplex Division . . . an ultra-modern plant designed from front to back to give you fast, dependable service on valves and meters. New manufacturing techniques, updated assembly lines and ample manufacturing capacity and a complete staff of skilled workers have all been planned around the single objective of getting your orders to you on time and built to your exact specifications.

Installing a trunk main in Queens. The Mayor of New York, Hon. Robert F. Wagner; Armond D'Angelo, Commissioner of the Department of Water Supply, Gas and Electricity; Edward J. Clark, Chief Engineer.

REPORT FROM NEW YORK CITY

685,000 ft of steel pipe—and never a break!

New York's experience with large-diameter steel mains dates back to 1910—nearly 50 years. In fact, since the mid-twenties, the City has specified steel pipe for mains 30 in. ID and over. The City now has in operation some 685,000 ft—130 miles—of steel pipe.

The chief reason for using steel has been to avoid the tremendous damage that can be caused by the breaking of mains made of brittle materials, resulting in the flooding of subways, basements, etc. New York's policy has paid off. All steel mains have been in virtually continuous operation since their installation, with never a major failure.

Large-diameter steel pipe, coated and lined with coal-tar enamel, is unexcelled for water transmission and distribution mains. No other material can equal its resistance to damage due to external loadings. It withstands impact and vibration; it has the beam strength to span washouts. And modern, protective materials maintain its continued high flow capacity indefinitely.

Most of the nation's major cities regularly specify tar-enameled steel pipe. It's pipe you can rely on. We'd be glad to tell you more about it. Please contact the Bethlehem sales office nearest you.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation
Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

New Nalco Coagulant Makes Bigger, Heavier Floc . . . Faster

Nalcolyte 110 boosts Capacity of existing Treatment facilities

Nalcolyte 110 is a new, non-ionic polyelectrolyte of very high molecular weight—over 1,000,000. It is used with conventional coagulants such as sodium aluminate and alum to increase size, density and uniformity of the floc.

May be used in public water supplies

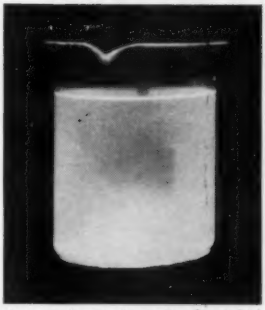
Approved by the U. S. Public Health Service Technical Advisory Committee for use in treatment of public water supplies, Nalcolyte 110 speeds formation of tough, high-density floc as shown in the photos at right. In this case a single ppm of Nalcolyte 110 replaced 30 ppm of a conventional coagulant . . . *and produced a clearer water.*

Greater Capacity; Better Water

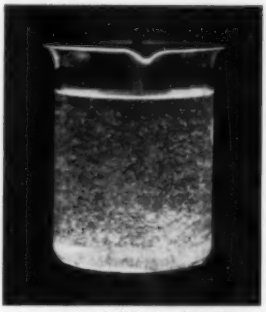
Small dosages of Nalcolyte 110 produce a fast-settling floc that permits increased throughput without danger of carryover and plugging of filters. If your problem is to produce clearer water, and more of it, Nalcolyte 110 is the newest, most feasible answer.

Full Data Available

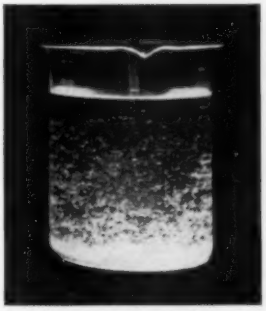
Write or call for details on this new, potent coagulant today . . . for better flocculation . . . greater capacity . . . lower costs.



Untreated control sample of a turbid raw water.



Same water with 50 ppm alum added, photographed 7 seconds after ceasing agitation.



Same water with 20 ppm alum and 1 ppm Nalcolyte 110 added. Photo 7 seconds after stopping agitation shows rapid settling rate of larger, denser floc.

National Aluminate Corporation is now

NALCO CHEMICAL COMPANY

6216 West 66th Place Chicago 38, Illinois

In Canada: Alchem Limited, Burlington, Ontario

Nalco®

. . . Serving industry through Practical Applied Science

Nalco CHEMICALS

PHOTOVOLT
pH Meter Mod. 115

A full-fledged line-operated pH Meter of remarkable accuracy and stability at the low price of

$145

- SIMPLE IN OPERATION AND MAINTENANCE
- FAST AND DEPENDABLE IN SERVICE

Write for Bulletin #225, also for literature on other Line-Operated and Battery-Operated Photovolt pH Meters

PHOTOVOLT CORPORATION

95 MADISON AVENUE NEW YORK 16, N. Y.

Also: Multiplier Photometers, Exposure Photometers for Photomicrography, Hemoglobinometers, Glossmeters, Polarimeters, Foot-Candle Meters, Interference Filters, Mirror Monochromators

Always fair weather

. . . the Dresser way

Lenoir, North Carolina engineered this 10-mile, 20-inch water supply line to supply an additional 3 mgd. Gilbert Engineering and Pat O. Chester Construction Co. laid the 100 per cent Dresser-Coupled steel piping in 40 and 50 foot lengths.

When you specify Dresser® Couplings, you are much less vulnerable to delays caused by bad weather. If your crew can get in the trench, they can make the connections. All you need is a simple hand wrench to make permanently tight joints . . . no need for expensive welding equipment, no costly weather delays! And unlike rigid joints, the non-rigid Dresser Coupling protects the pipe from ground movement and stresses, remains bottle-tight even when absorbing shocks which can create costly maintenance problems in other piping.

GET THE MOST FOR YOUR TAX-PAYER'S DOLLAR: Be sure to specify Dresser-Coupled steel pipe on your next water line for the *least initial cost, lowest maintenance!*

Two man-minutes per bolt make bottle-tight joints for life!

Bradford, Pennsylvania

Chicago
Houston
New York
S. San Francisco
Toronto & Calgary

DRESSER MANUFACTURING DIVISION

ONE OF THE DRESSER INDUSTRIES

NEW!
EPON® 1001
INSIDE COATING

The most important potable water news in years!

. . . For all piping—metal, concrete, tile
. . . For any water condition
. . . For any practical flow rate, *and now*—
. . . Meets existing public health requirements

Among the toughest, most durable resins known to modern chemistry, Shell Epon 1001 is an ideal interior pipeline coating for potable water lines. It has an outstanding record of performance as a chemical-resisting coating for oil pipelines, tank interiors, and as a finish coating for appliances, trucks, and plant equipment exposed to corrosive fumes.

Conventionally cured coatings of Epon 1001 have truly remarkable adhesion, especially to metals, excellent resistance to impact, cavitation, and abrasion. Outstandingly resistant to water erosion, Epon 1001 interior pipe coatings have given years of service, even in difficult water areas, with no perceptible deterioration or contamination of supply.

Epon 1001 may be applied by brush, spray or pig. Setting takes place at room temperature within an hour or so. Curing time may be considerably shortened by the application of heat.

The best news of all is that Epon 1001 pipeline coating can reduce your maintenance costs, no matter what your potable water condition . . . and often enables you to supply higher purity water.

Contact your nearest Shell Chemical district office for complete information on this important new development. Your Shell Chemical district representative has all the facts you need to help you get started right away.

EPON puts the power in paint

HELL CHEMICAL CORPORATION
PLASTICS AND RESINS DIVISION

District
st Touhy Avenue
48, Illinois

East Central District
1578 Union Commerce Bldg.
Cleveland 14, Ohio

Eastern District
50 West 50th Street
New York 20, New York

Western District
10642 Downey Avenue
Downey, California

IN CANADA: Chemical Division, Shell Oil Company of Canada, Limited, Toronto

SHELL

MORE WATER FOR MIDLAND

Armco Pipe feeds new 100-million-gallon reservoir at Midland, Michigan

Midland, Michigan, is joining hundreds of other cities using Armco Welded Steel Pipe to meet increasing demands for water supplies. Shown here is the 36-inch-diameter Armco Pipe being installed for the inlet of Midland's new 100-million-gallon reservoir.

This reservoir is part of Midland's continually expanding water supply program. Over the past eight years, nearly 30,000 feet of Armco Pipe in various diameters from 8⅝ inches to 36 inches have been used to help meet the city's need for more water.

Armco Pipe can help solve *your* water supply problems too. Write us for information related to your particular requirements. Armco Drainage & Metal Products, Inc., 4339 Curtis Street, Middletown, Ohio.

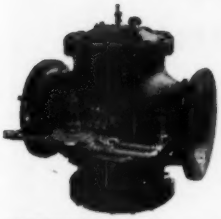
ARMCO DRAINAGE & METAL PRODUCTS

Subsidiary of ARMCO STEEL CORPORATION

OTHER SUBSIDIARIES AND DIVISIONS: Armco Division • Sheffield Division
The National Supply Company • The Armco International Corporation
Union Wire Rope Corporation • Southwest Steel Products

1879—ROSS—1879

Automatic Valves

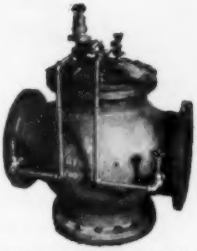


ALTITUDE VALVE

Controls elevation of water in tanks, basins and reservoirs

1. Single Acting
2. Double Acting

Maintains safe operating pressures for conduits, distribution and pump discharge



SURGE-RELIEF VALVE

REDUCING VALVE

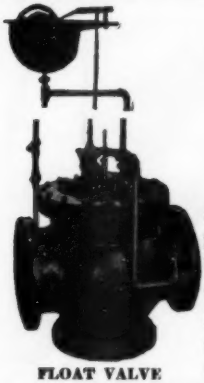
Maintains desired discharge pressure regardless of change in rate of flow

Regulates pressure in gravity and pump systems; between reservoirs and zones of different pressures, etc.

A self contained unit with three or more automatic controls

COMBINATION VALVE

Combination automatic control both directions through the valve.

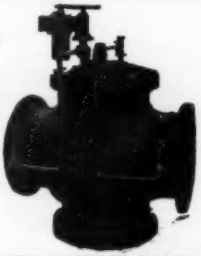


FLOAT VALVE

Maintains levels in tank, reservoir or basin

1. As direct acting
2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

Electric remote control—solenoid or motor can be furnished



REMOTE CONTROL VALVE

Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

Packing Replacements for all Ross Valves Through Top of Valve

ROSS VALVE MFG. CO., INC., P. O. BOX 593, TROY, N. Y.

the V-notch
is the difference in chlorine control

Safe chlorine control is the job of a chlorinator.
This control, the V-notch, does the job completely.
Yet it appears to be simply a grooved plug in a ring.
It is, of course, more than that... much more.
The groove in the plug is precision milled and shaped so that when you turn the control knob on your chlorinator and the plug slides through the ring, the size of the opening between the groove and the ring changes an exact amount. You meter chlorine exactly and simply because every position of the plug in the ring makes a repeatable orifice size—a repeatable chlorine flow rate.
Only in a W&T V-notch Chlorinator is control so simple, so true, so precisely right.
And, of course, the right plastics make the whole chlorinator chlorine-proof.

A booklet, "The V-notch Story" will tell you about all the W&T V-notch Chlorinator features. For your copy write Dept. S-127.05

WALLACE & TIERNAN INCORPORATED
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

Lauren W. Grayson, President 1959–1960

Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 51 • JULY 1959 • NO. 7

Water Resource Development and Management

Luna B. Leopold

An address presented on Mar. 11, 1959, at the Illinois Section Meeting, Chicago, Ill., by Luna B. Leopold, Chief Hydraulic Engr., USGS, Washington, D.C.

IN a sandy, riverside location in Wisconsin, my family has a farm, once abandoned by a previous owner because it would not produce much corn. By the time we bought it—for a pittance—only a few remnants of white pine remained from the magnificent stands made famous by the Paul Bunyan legend. In this part of Wisconsin the pines were, even originally, restricted only to patches of the better soil, and the variability of the glacial topography had resulted in an interesting mixture of prairie marsh, swamp woodlot, and sand hill.

We did not acquire this farm because it had a great potential for growing crops. Rather we were interested in the variety of ecologic and topographic types, which, even within the confines of our property, represented a condensed version of the many different types of land in the Wisconsin countryside. The farm also has a very peculiar aesthetic and historical interest. Marquette's canoes once slipped quietly past our favorite fishing hole on the river; passenger pigeons once roosted in our great oaks; and the few remaining white pines silhouetted against the sky-glow of evening made one think of the Round River and the Blue Ox.

After we had acquired the place, the problem arose of what we were to do with it. Its resources were limited and peculiar. They had little economic value—all the more reason that they should be carefully appraised in order that they be fully utilized and appreciated. While we were hammering and sawing the old stable into a usable homestead, we investigated every coulee and covert, every thicket and thatch. By compass and pace we mapped the boundaries, sketched in the topography and vegetation, and made notes on the distribution of soil and the occurrence of water. We counted the various kinds of birds and found

there was a reasonable population of woods species, mostly transients. There were no pheasants, no quail, practically no grouse, and in spring only an occasional woodcock.

With the analysis of what we had to work with we started immediately on the task of development. The techniques were chosen to achieve specific goals. We wanted, over a long period of time, to grow a stand of conifers which would yield both pleasure to the eye and logs to the saw. We could see the possibilities of having quail, pheasants, grouse, and deer, and of extending the stay of some of the migrant species.

We set to work with shovel and axe, wire and nails, and a will to succeed. Trees were lopped so that they formed brush piles. Wild grapes were brought in and planted on the brush piles. We removed grass with a shovel where it was competing with desirable wild flowers, and planted little patches of corn and beans.

Within a few years there were pheasants, grouse, and woodcock to shoot, wildflowers to delight the eye, and the annual increments on the stem of every pine represented increments of future dollars in the bank.

The problems of appraisal, development, and management are essentially the same for all resources. Resources may be renewable or nonrenewable. With renewable resources the problem is to increase, as far as possible, the yield of each increment. With nonrenewable resources the problem is to develop them intelligently and without waste. It is necessary at the earliest possible stage to make an adequate appraisal of the characteristics and distribution of the resource and, on the basis of the facts obtained, to map out a plan of development and management. The initial appraisal may be done by pace and compass or with the most modern of scientific instruments. A good appraisal must evaluate all of the important aspects of the resource and not merely one. A resource appraisal is not something that is done once and then forgotten. Because the resource itself is constantly changing, it is necessary to follow up the general study with continuing measurements, usually on a sampling basis.

Resource development and management must be based both on estimates of future needs and on the potentialities of the available resource. On our farm, for example, we had to decide what it was we were trying to achieve. Many of our choices were between economic and aesthetic values, because the aesthetic values, such as scenery or solitude, had to compete dollarwise with other possible uses of the land. It was necessary to decide at the outset which aesthetic values were to be preserved. We had to decide, for example, whether the one fertile part of our prairie should be devoted to growing wildflowers or corn. For us the choice was easy; the spring blush of gray and green, punctuated by the white pergolas of flowering baptisia, was far more important than the few dollars the area could yield in corn.

Though much more complicated, the allowable degree of pollution of our rivers is a matter of choice in which certain aesthetic values may be obtained only at the sacrifice of certain economic values. But in deciding among various possible developments, all alternatives must be considered seriously and carefully.

The period of resource development is characteristically much shorter than the subsequent period of management. It did not take us very long to com-

plete the construction of brush piles, the transplantation of flowers and trees, and the finishing of the rude homestead. Then followed, and continues, the constant culling of undesirable trees from the woodlot, the thinning, the weeding, and the seasonal burning of trash.

Management of Water Resources

The United States has nearly completed the development of its water resources and must now prepare to manage them. That the nation has reached this point is abundantly clear. It is well known that in much of the West the available water resources are nearly fully appropriated. It is now necessary to inspect more carefully the nature of the unused, lost, or wasted portion of the resource to see whether it can be brought under control and managed for productive use.

In a recent paper, Raymond L. Nace (*1*) compiled a general budget of the total water resource, with the view to identifying those general parts of the resource which offer management opportunities as yet unused. He estimates that in the United States ground water occurring at depths less than 2,500 ft is equivalent to the total of all recharge during the last 160 years. There is, in other words, a sizable reserve which has been accumulating over a long period of time. Nace concluded that at the present time by far the greatest opportunity for new management practices lies in the field of ground water.

Need for Appraisals

There is at this time only an incomplete picture of the water resources of the country. We have certainly not made more than a beginning on a real state-by-state appraisal of the resource, and a quantitative picture of the water budget, however rough present knowledge would require such a budget to be. Although we in the water resource field talk a lot about water appraisal, it becomes apparent, when our activities are studied in detail, that our effort has placed a disproportionate emphasis on the collection of data. We are not really putting enough measurement data into practical use for management. For example, estimates of ground water resources, including the requisite subsurface geologic information, have been completed only for a few basins. With regard to the surface water resource, the samples represented by stream-gaging data have been obtained at 10,000 sites in the United States. Although this is better coverage than in any other large country in the world, it still is not a large sample of the more than 3,000,000 mi of surface streams in the United States. More of this information on streamflow must be analyzed, together with ground water information. A water budget must be compiled for each basin, aquifer, or other hydrologic unit, so that the possibilities of management can be evaluated.

Although water resource development is approaching maturity, and in some basins in the West development may be essentially complete, we are hardly beginning to think about the much longer period ahead of us in which the principal water problem will be one of wise management. We still lack many of the essentials for a program of wise management. First, though our store of facts is relatively good, we have yet to translate these facts into adequate appraisals. Second, and more important, our basic understanding of the mechanics and processes in the land portion of the

hydrologic cycle is severely limited. Although many details about the hydrologic cycle are known, in terms of what is necessary for wise and efficient management of the water resource, it is my opinion that our detailed knowledge of hydrologic principles is woefully incomplete.

We lack a third important ingredient in any scheme of resource management. We must make certain generalized decisions concerning what we, as a people, want to be and have. These decisions must be made on the basis of aesthetic values as well as economic ones. As a people, we must decide what we want in the way of clean streams, of natural scenery, recreation, and beauty—all of which compete with the economic possibilities of resource development.

Engineer's Responsibility

The engineer has a peculiar responsibility in this field of water development—which responsibility, in my opinion, is too often inadequately discharged. It is up to the engineering specialists not only to analyze and appraise the magnitude and characteristics of the resource but also to present this information to the public in such a way that a philosophy about management and use can gradually emerge. Before we transmit the facts to the public, however, there is a need for the delineation of general concepts. We in the engineering profession must ourselves analyze water problems and water facts in sufficiently broad terms that we can develop generalizations on which we may base a professional point of view. I suggest here one such generalization: America is now entering a period in which water management rather than water development will be the major engineering task. If we accept this generalization as true, the nature and scope of necessary data, management techniques, and appraisal studies must be reframed in managerial terms.

Meaning of Management

Let us clarify what is meant by management. The intelligent management of money consists of making sound investments that give a satisfactory balance between risk of loss and financial return. The management of water might be considered in an analogous way. To make a sound investment of water resources would be to apply water to fitting and reasonable uses—that is, uses that are consonant with the quantity, variability, and quality of the supply. The "risks" in the field of water investment might be defined as undue depletion or unnecessary degradation of the quality. Return on the investment might be the number of times a given supply is used and the social benefits accruing from these uses.

Probably the most obvious type of water management is reservoir storage, in which flow that occurs during periods of high runoff is stored and released later during periods of low flow. A higher type of management is the release of reservoir storage for developing hydroelectric power and meeting other needs, such as irrigation, at the same time. Reservoir operation involving more than a single use of stored water is often complicated by the fact that power demands have quite a different time schedule from other demands. To generate the maximum amount of power while simultaneously meeting irrigation or municipal supply demands requires considerable skill. Also, scheduling reservoir releases for such multiple use

becomes increasingly efficient with increased skill in forecasting not only the timing and volume of demands, but the volume of expected runoff. Add to these considerations the relation of evaporation losses to the area of exposed water surface—a factor of importance in semiarid or arid areas—and reservoir operation becomes an art requiring great skill.

In large river basins a system of reservoirs presents even more complicated problems. The need for unfilled reservoir capacity for flood control is sometimes a factor, although in most reservoir systems, flood control capacity is generally kept separate and additive to capacity for holdover storage.

Reservoir operation is only one form of water management in widespread use today, however, and in the present discussion I wish to consider management in a larger context. Consider, for example, the much more complicated system of water relations in a drainage basin, and let storage include reservoir storage, ground or aquifer storage, and soil moisture; let water use include municipal, industrial, agricultural (both dry-farmed and irrigated), and recreational uses; and let availability mean the amount of water at a given place at a given time. Availability, of course, is interrelated with utility of water—that is, the applicability of a given quality to a particular use.

If storage is to include the use of aquifers as underground water reservoirs, much additional knowledge is needed. Some of the advantages of underground storage are quite obvious. Evaporation losses would be minimized. Underground storage eliminates the gradual replacement of usable storage capacity by sedimentation, which is a disadvantage of surface reservoirs. At present, however, the techniques for getting surface water into an aquifer efficiently and in sufficiently large volumes are inadequately developed. Only in a few exceptionally favorable geologic, topographic, and hydrologic situations is artificial recharge practiced at present. Infiltration by surface ponding involves difficulties in the maintenance of sufficiently high permeability. Well injection is hampered by a tendency for clogging of pores by chemical precipitation, air bubble locking, sediment, or organic substances. Induced infiltration by manipulation of ground water levels and by operation of surface storage reservoirs is still in its infancy.

Management, in this broader context, requires foresight in identifying both possibilities and difficulties, and the initiation of investigations of ways to overcome the difficulties.

Appraisal, from the standpoint of management, is not merely the collection of records. To record history is neither appraisal nor management. Records are used to evaluate the characteristics of the resource. The function of management is to project these characteristics into the future, forecast the results of alternative actions, and develop plans utilizing these forecasted results to attain desirable results.

Because forecasts usually require additional knowledge and experience, part of the task of appraisal is to identify the nature of such needed knowledge and experience and to arrange for obtaining it. Thus management can mean both advance planning and day-to-day operation.

Problems in Management

Once an appraisal has been made that is sufficiently complete to allow some reasonable generalizations to be

made about the amounts, variability, and quality of water in various districts or areal units within a basin, if a particular industry wished to know possible places with certain amounts of water available, the proper governing body would inquire first concerning the minimum quality characteristics necessary for that industry and then about the amount and types of waste products that would be discharged. The appraisal information would reveal those areas where the water would satisfy the minimum quality requirements. An industry requiring water only for cooling might use a water with a higher concentration of salts than would be fit for municipal use, and would be urged to use the lowest quality water that would meet the needs. The areas that might supply such water would then be considered in terms of the effects of the pollutants to be discharged by the industry. One area might have enough flow during the entire year that satisfactory dilution would render the effect of industrial pollutants unimportant. In another area, any permit to use water might include a provision that the industrial user undertake a specified treatment of wastes before discharging them into a stream. Good management requires recognition that such choices will have to be made. Particular kinds of information and data must be available; such information must be used in advising industry and making decisions concerning the issuance of water use permits.

If a municipality foresaw a need for additional water, it could, from the appraisal data, determine upon various physical alternatives. Analysis of the data, coupled with the experience of water users in the area, might point to several alternatives, which might include both ground and surface sources. Let us assume that if a surface supply were developed it would compete with certain recreational and wildlife needs. A cheaper solution could be the development of wells to tap a ground supply, provided that the aquifer were not already fully utilized for supplementary irrigation.

Water Rights

It is not sufficient to say that municipal use has a higher priority than agricultural use. Although this may be sound as a broad generalization, it is not a criterion which could by itself lead to a decision unless life or health were an issue. Moreover, legal doctrine does not necessarily lead to a single, clear-cut answer. In the field of ground water, particularly, it is difficult even under optimum conditions to define what water belongs to whom. Much depends on the hydrologic relation of the recharge area to the point of use, the relation of surface streams to recharge, and the effects of the location and amount of withdrawal on the rate and source of recharge. In other words, although a legal doctrine may be quite clear, its application in any given instance depends heavily on hydrologic facts and physical interrelations.

The administrative machinery of commissions, boards, committees, or executive directors, however powerful or well coordinated, can neither prevent nor solve water problems ex cathedra. Two things are vitally necessary for such officers or groups to be effective: [1] an understanding of the hydrologic environment within which their authority is exercised, and [2] an informed public whose aspirations and needs are known. The public must be made aware of both the

hydrologic environment and the broad social needs of community and state. It is not enough to consider local and financial aspects. It is obvious that these requirements can only be met if there is sufficient understanding of the water resource and the physical relations that affect it.

Some areas and some groups are entering the phase of water management which I have tried to picture. One of the most significant examples was a recent action by the state engineer of New Mexico, S. E. Reynolds. Recognizing the hydrologic fact that surface streamflow is intimately interconnected with ground water in the permeable valley deposits of the Middle Rio Grande Valley, Reynolds declared that withdrawals of ground water in that valley amount to diversions from the river, and are therefore subject to the same rules of appropriation. This decision is outstanding because it exemplifies so clearly that hydrologic considerations can and must eventually become one of the bases for administrative action.

Water problems do not usually arise until competition develops, but as resource development progresses, and particularly during periods of less than normal supply, competition for the water intensifies. It is my opinion that no law, series of permit regulations, or priority rating between municipal, industrial, and agricultural use can automatically solve such problems. I do not believe that an appropriation rather than a riparian doctrine would necessarily prevent water rights problems from arising, or, indeed, that any one doctrine would necessarily, by itself, make the problems more amenable to solution. It is for this reason that I have stressed the concept of water management rather than to recommend specific kinds of legislative doctrine, rules of priority among uses, or administrative procedures.

Conclusion

No matter what type of resource is under consideration, sound management principles should accompany development from the very beginning. Development and management, in turn, depend on an adequate system of continuing appraisal. We, the engineers and other scientific personnel who consider ourselves experts in the field of water, are trying to operate the complex mechanism of modern water resource development with an outmoded tool kit for water appraisal.

Management means the intelligent application of data and knowledge in a framework that allows flexibility of action. Management implies the liberal use of horse sense rather than legal horsepower. Horse sense can be used to good advantage only when there is enough knowledge to permit choices to be framed in some sort of rational terms.

Reference

1. NACE, RAYMOND L. Water Management: Agriculture and Ground Water Supplies. USGS, Washington, D.C. (*in press*).

Progress in the Development of Municipal Supplies

Edward F. Taylor

A contribution to the Journal by Edward F. Taylor, Taylor & Smith, and City Attorney, Redlands, Calif. This paper originated as part of a report presented to the convention of the National Institute of Municipal Law Officers, Chattanooga, Tenn., by the author, as chairman of the Committee on Municipal Water Problems, and published in the 1959 NIMLO Municipal Law Review.

WATER shortage breeds water litigation. Knowing this, municipal attorneys are taking the lead in urging the development of supplemental water for future growth. When there is not enough water to go around, sound legislation and water projects may be of far greater service than a prolonged legal battle. Lawsuits do not produce more water.

Alarming shortages are cropping up, not only in arid areas, but in every section of the nation. Water is unequally distributed over forest, swamp, and desert. Long-range scientific estimates show that the climate will be drier before it gets wetter, which indicates danger for marginal areas. The tremendous growth in municipal and industrial use adds to the emergency.

For one reason or another—inadequate planning, insufficient storage facilities, overpumping, overuse of underground supplies, and increases in consumption—more than 1,000 communities, or 15 per cent of the population, have had to ration water in the past 5 years. This is why Senator Clair Engle's bold new federal program for the development of municipal water is supported by many municipal leaders. Engle will introduce a bill for joint financing of federal-state projects with major outlays of money for municipal water. As chairman of the Committee on Interior and Insular Affairs, House of Representatives, Engle pointed out that existing federal water programs have "one obvious gap: no provision exists in present federal law for the federal government's participation in projects primarily for the development of industrial and municipal water, which is a field of growing importance in all areas of our nation." Engle will propose legislation under which the United States will advance money for such projects on a nonreimbursible basis, and interest-free loans for amounts allocated to irrigation.

Need for Planning

The master-plan approach, so essential in the zoning field, is the key to orderly development in water supply. This is certainly true of cities that are expanding rapidly.

City water systems are designed primarily to serve the present and future municipal area, not scattered suburbs. Expanding outlying areas do not come

within the city jurisdiction until annexation.

Those in charge of city utilities should have an intelligent annexation policy and follow it consistently to guide the extension of municipal water service. Realizing this, officials of Fort Wayne, Ind., adopted a master plan when the ground water supply failed to keep pace in quality and quantity with population increase. The principal aim of the plan is a blueprint for the orderly development of transmission or feeder mains and impounding reservoirs. One of the greatest aids is the aerial survey (*1*).

Honolulu has projected its water resources program at least 25 years into the future (*2*).

The South Bend, Ind., water development program has turned a municipal water problem into an industrial development bonanza over the last 3 years. The success of the program is evidenced by South Bend's report of a gain of 36 new industries and the expansion of another 26 industries in the area (*3*).

Although droughts are generally blamed for water shortages, the real fault frequently lies in improper planning. For instance, 21 southern Iowa cities that use impounding reservoirs as a source of water have experienced severe shortages. Water had to be brought in from a distance and rationing was imposed. Many inadequacies were due more to improper hydrologic design than to lack of water, according to one study (*4*). The same problem plagues Missouri cities in the small drainage areas remote from the Mississippi River. Some cities provided adequate reservoir space in advance of the drought, and others have done little to correct the causes of their shortage of water.

An example of the need for planning in the midst of plenty is Louisiana where municipal use has increased by 100 mgd since 1950. More than 65 times as much water travels down the Mississippi River as is used by the entire state of Louisiana. Cities, farms, and industries along the river's bank enjoy an almost untouched source of water. Not far from the Mississippi, however, are points of acute need (*5*).

Forest, Miss., plans a new well of a capacity equal to or greater than the combined capacity of the two present wells, additions to the iron removal plant, and a new elevated tank of 400,000–500,000-gal capacity (*6*).

A 7-mi line to Guntersville Lake for water is permitting the continued growth for the city of Albertville, Ala. (*7*).

Reduction of leakage and waste in the distribution system and accurate metering of sales are normal elements of every good management program, and they are too often neglected. Water crisis came to Michigan City, Ind., at the edge of Lake Michigan's limitless supply, because of the unfortunate location of its water works and a major leak in its main line, which went undetected for several years (*8*). Too many communities find that their unaccounted-for water is as much as 50 per cent of the total pumped into the city's system. The loss is largely caused by leaks in water mains and service connections to homes, but it is frequently caused by underregistration of meters. Aggressive leak detection programs can cut this waste dramatically.

Cities throughout the nation have stepped up their programs for supplemental water to prepare for the doubling of water use expected in the decade ahead.

Elmira, N.Y., relies upon Chemung River water stored in a reservoir, but new demands have forced the city to augment its supply with deep wells.

The Portland, Ore., Bureau of Water Works is constructing a new dam which will increase the storage volume by 60 per cent. At the present rate of population growth of Portland, it is estimated that this new reservoir will adequately supply the populace up to sometime between 1965 and 1970. The city then expects to tap six lakes in the area for additional supply. Current shortages in the northern section are being met by a $1,000,000 program of storage tank construction.

California Developments

Importing water by pipeline from areas of surplus to areas of need is the most practical solution to current water needs. As water shortages grow more desperate, this expensive approach will have to be adopted by more and more municipalities The Los Angeles supply is the best known example of this approach. Los Angeles went 240 mi to the Owens River for its first supplemental supply and has since tapped Mono Lake, 350 mi away, and the Colorado River, 450 mi away.

The Metropolitan Water District, established to import water from the Colorado River, includes 83 cities and large unincorporated areas covering 3,198 sq mi, a population of 2,035,371 and an assessed valuation of nearly $2 billion.

San Diego County, at California's southern tip, has begun construction of its second major aqueduct. A contract has been awarded by the San Diego County Water Authority for the first 10½-mi section of the aqueduct, which will be more than 100 mi long. Water will be imported from the Metropolitan Water District, which will build 40 mi of the line. A $35,000,000 bond issue, approved in July 1958, will pay for the project. Inasmuch as the aqueduct crosses undeveloped area, the county authority has under advisement requests for annexation of 72,000 additional acres of land—a step toward gaining supplemental Colorado River water (*9*).

Another municipality using Colorado River water acted to meet future needs. Voters of the city of Fullerton approved a $3,700,000 bond issue by five to one. Bonds will be paid off with revenue from water department operations. This revenue will finance reservoirs and the purchase of land for additional reservoirs and increase the number of transmission lines and booster stations (*10*).

Newport Beach, Calif., is completing construction of a new reservoir designed to hold about 40 times the capacity of its present 4.5-mil gal storage facility. Demonstrating the effectiveness of organized citizen action, a 35-to-1 majority favored the $1,780,000 bond issue. About half of Newport's water comes from city-owned wells, and the other half comes from the Metropolitan Water District. Salt water intrusion in recent years has resulted in a steadily diminishing well supply (*11*).

Voters of the East Bay Municipal Utility District (EBMUD) approved a $252,000,000 bond issue, launching a huge water development program. EBMUD now services a population of 1,100,000 in Alameda and Contra

Costa counties. The total will grow to 1,296,000 by 1967. Water consumption in EBMUD is now nearly five times as great as in 1923 (*12*).

In the San Francisco Bay area, where the population is currently growing at the rate of 100,000 per year, it is planned during the next 50 years to obtain water from local sources, from expansion of present import systems, and from two authorized but presently unconstructed projects, the North Bay Aqueduct and the South Bay Aqueduct. The latter aqueducts must be financed either at the state or local levels, or on a partnership basis.

San Francisco proposes eventually to expand its Hetch-Hetchy system and import up to 448,000 acre-ft of water annually from the Tuolumne River. The city's storage reservoirs now are capable of developing 291,000 acre-ft annually.

California's Department of Water Resources recommended a $47,700,000 plan for supplying water to the south San Francisco Bay Area along two arteries. One would be a 43-mi aqueduct from the Sacramento–San Joaquin Delta to supply Alameda, Contra Costa, and northern Santa Clara counties, and the other a 6-mi tunnel from the proposed San Luis Reservoir to serve San Benito County in the Hollister area. Both would be part of the huge Feather River Project, presently held up because of failure of the 1958 legislature to agree on funds for the undertaking. The department's report said supplemental water needs of the South Bay area for the next 50 years will increase from the present 80,000 acre-ft a year to 265,000 acre-ft (*13*).

With a view toward possible future importation of northern California water, landowners in Kern County formed the Semitropic Water Storage District.

Two other districts being formed in Kern County are the Rosedale–Rio Bravo Water Storage District, west of Bakersfield, 45,000 acres, and Maricopa Water Storage District, 125,000 acres. Totaling 225,000 gross acres, Semitropic is the state's largest storage district for supplementing local supply by importing water from surplus areas. Serious ground water depletion in this rich California farm region led to the overwhelming vote approving the district.

Other States

Tacoma, Wash., recently completed two new reservoirs, one of 50-mil gal and the other 100-mil gal capacity (*14*). Bremerton, Wash., has developed and uses five surface sources in addition to seven wells. The one most recently developed is the Union River, which has a watershed area of only 3.2 sq mi (*15*). In North Carolina, Charlotte's new filter unit and pumping station will produce more than four times the current daily water consumption (*16*).

Among the smaller communities, Midwest City, Okla., expanded its well supply to serve a population of about 30,000 people. To satisfy the ultimate saturation point of about 50,000 people, the city plans to develop another water source shortly after 1960 (*17*).

Midland, Tex., which has had a rapid population growth since 1940, ordered the construction of 5-mil gal storage tank, the installation of two booster pumps and connecting facilities (*18*).

Illinois boasts of successful attempts to solve local water problems. The state legislature passed two bills to permit Chicago to construct water

works facilities beyond its city limits (a distance of 35 mi) to supply Lake Michigan water to the growing metropolitan area. Outstanding action of various kinds has been taken in recent years by Peoria, Jacksonville, Decatur, and several other cities. In 1955, Jacksonville completed a 23-mi pipeline to a collector-type well constructed beside the Illinois River at a cost of $2,750,000. The project, financed without federal aid, is expected to solve a 100-year-old problem of water shortage. Through the cooperative efforts of the Peoria Association of Commerce, the State Water Survey, and the municipalities, industries, and utilities in the Greater Peoria area, a long-range program is going forward to solve the water problems of this area. Infiltration pits, designed to replenish Peoria's ground water supplies with water from the Illinois River, were so effective they attracted nationwide attention.

Other Illinois cities that have brought their water source development and facilities up to date are Bloomington, Shelbyville, Mt. Carmel, East St. Louis, LaSalle, Granite City, Sandoval, and Melrose Park (*10*).

A 30.6-mi pipeline will solve the water supply problems of Galesburg, Ill. The people expressed their approval of the project to tap aquifers adjacent to the Mississippi by a 57 per cent majority vote (*19*).

When wells were unable to produce enough water for the booming little town of Griffith, Ind., town officials decided to purchase water wholesale from the Gary-Hobart Water Corp., a privately owned utility (*20*).

In a unique approach to water supply, Plymouth, Mich., purchased a 10-acre tract of land over glacier moraine and expects to double its water supply from this source (*21*).

Illinois' principal problem arises in the "uplands" communities in areas away from the Mississippi River where there is inadequate groundwater supply. The need for more reservoirs is being met by the municipalities themselves, and, in the populated unincorporated areas, by public water districts organized by statutory authority.

To solve municipal water supply problems in South Dakota, fluctuating flows are regulated by a high-capacity, low-head pump, floated on the river outside of the plant. In Mobridge, S.D., extra water was released from the upstream dam.

In addition to construction on the Missouri River, work is proceeding on tributary streams to furnish water to Lemmon, on the South Dakota–North Dakota border, and Rapid City, a popular tourist center and the location of Ellsworth Air Force Base (*22*).

New Jersey's ultimate goal is a new major supply for the northeastern metropolitan counties and in the Raritan Valley. For long-range water needs, the state looks to the Delaware Valley and the Raritan River Basin. Whether these supplies will be realized depends on a US Supreme Court decision to establish the rights of New Jersey and several other states claiming Delaware River water, joint legislation by these states, and results of a current comprehensive survey by the US Army Corps of Engineers.

In 1958, New Jersey authorized its Department of Conservation and Economic Development to develop the 55-bil gal Round Valley Reservoir and the 10-bil gal Spruce Run Reservoir in Hunterdon County.

Many cities in the Great Lakes region are stymied by an agreement with

Canada which prevents the transfer of Great Lakes water outside the natural drainage area of the lakes. Illinois brought the question up by petitioning Congress 30 years ago for permission to use Lake Michigan water to flush Chicago's sewage into the Mississippi River. Canada, joined by Great Lakes states, insisted on the restrictive agreement in order that lake levels would be maintained.

Cities such as Akron, Ohio, and Cleveland, which lie inside the Lake Erie Basin, plan a 16-mi pipeline to bring water to the Cuyahoga River for their future use.

Watersheds

The responsible law officer should urge officials to look beyond the reservoir to the watershed. Water supply is more than reservoirs, pipelines, and pumping stations. One must not forget the ultimate source of the water on the theory that good water will always issue forth from the hills and forests.

When forest fires affect the water supply, the city that taps basins supplied from the watershed is vitally concerned. The same is true where overgrazing induces erosion. If vegetation covering watersheds can be manipulated to the benefit of water users, municipal officials should be the first to do so. There is a need for water authorities to take an active interest in all activities which may possibly affect water supply.

The Portland, Ore., contract with the US Forest Service for cooperation in planned watershed experiments, which may ultimately benefit both the city and the nation, is believed to be the first such municipal program of watershed research (*23*).

An Alabama law creates watershed conservation districts "for the purpose of developing and executing plans and programs relating to any phase of conservation of water, water usage, flood prevention, flood control, erosion prevention and control of erosion, floodwater, and sediment damages" (*5*).

Often the most practical means of developing supplemental water is close at hand and there is no need to look elsewhere for water to recharge overdrawn basins. If suitable withdrawal works are placed next to a source of supply, natural discharge may be induced into water-bearing formations. Such water systems are in wide use. At Manitowoc, Wis., two installations are so located and constructed as to induce recharge from Lake Michigan. Superior, Wis., gets the same result from well screens under Lake Superior. In former years, infiltration galleries lying parallel to Wisconsin streams or lakes at Hayward and South Milwaukee were used as sources of supply, and a similar installation is still in use at Nekoosa, Wis. Wells may be located near lakes and streams to improve the yield of ground water.

In addition to these methods of inducing natural recharge, artificial recharge is effective to set up fresh-water barriers against sea water. Californians have used various methods of recharge to combat salt water, notably at Camp Cooke, El Segundo, and Redondo Beach. On Long Island, N.Y., sea water is kept out by a requirement that well owners return used water in an uncontaminated condition into the ground, and at Brooklyn, N.Y., El Paso, Tex., and Camp Peary, Va., brackish wells have been recharged with fresh water.

Spreading as a means of recharge is most extensive in the western states,

and particularly in California. Proposals to use reclaimed sewage for recharge must be taken seriously as a conservation measure. Spreading by means of basins or impoundments has also been used extensively in New Jersey installations, such as Perth Amboy, Princeton, Lake Mohawk, and East Orange. In the central states the better known recharge operations are those at Des Moines, Iowa, and Peoria, Ill. (*24*).

Honolulu, confronted with a 50 per cent population increase in the next 20 years, is exploring every source of water. An intense program is now underway to conserve surface supplies by filtration and recharging of aquifers. Demineralization of brackish and sea water is considered an ultimate solution (*2*). Although Louisiana's average rainfall is twice the national average, there are small areas that rely upon rain catchment or storage of stream flow for household and farm use. Existing or potential shortages limit development and increase cost. The State Department of Public Works has improved some of these areas, and has some others under study (*5*).

Reclamation of irrigation water from sewage is proving a safe and economically feasible program in many cities, which are using effluents for agricultural and industrial purposes. Chicago and Baltimore are selling the effluent for power plant cooling and Denver is selling it for irrigation.

"Effluent can be used after primary treatment if it is stored in a reservoir for settling," reported Louis R. Howson. "The cases which create odor can be used for power production for pumping the effluent to elevations where it can be used."

Municipal and state governments must expect to shoulder a greater burden in planning their own water resources development in the future.

At present, the federal government and local agencies are not bridging the gap between what needs to be done and what is being done in water development. Most water experts concede the federal government will not provide enough money to the states to close this gap. For instance, during the past 10 years, California has spent $100,000,000 per year on water development projects, including $70,000,000 from the federal government. It is therefore up to the states to enter the field of water resources development with the objective of supplementing—not supplanting—the efforts of the federal government and local water organizations (*25*).

Cooperation

The current water crisis unites every water user in the drive to furnish enough water for the city, the farms, and industry. These various interests also compete aggressively for their share of the scarce supply, but they are finding that teamwork often solves their problems.

Costly duplication and assorted agencies working at cross purposes are too often characteristic of water resource management in many states and of the federal government, but the need to get the job done has led to coordination in this field. Wisconsin set up a Natural Resources Committee of State Agencies and New Hampshire now has a Council on Resource Development to provide a uniform approach. Other states have concentrated their resource agencies in a single department of conservation or

natural resources. In this way, Colorado brought fourteen agencies together in such a department.

Emergency water conditions have brought the nation to the threshold of new attempts at federal, state, and local cooperation. Many of the federal government's expensive water activities follow traditional lines, without any relation to state plans. A workable policy to coordinate these activities cannot be started too soon.

Municipal Government and Industry

Remarkable progress has been made by municipal government and industry toward a united approach to water problems. In Louisville, for example, the city and industry cooperate to stop pumping during cool weather, to recharge the aquifer with treated city water, and to conserve water by economizing on use. Large industrial users pump cool water during the summer months when city water is too warm. Storing of cool water during the off-peak season in the underground formations for use during peak periods has also been found successful at Louisville, Ky., Binghamton, N.Y., and Lubbock, Tex. (*24*).

At one time, industry in the Peoria, Ill., area was responsible for the discharge into streams of waste equivalent to that of a population of 2,000,000. This serious menace has been eliminated, because these industries cooperated to reduce industrial wastes by 95 per cent. Similar results have been achieved in other areas in Illinois.

To solve the problem of overdraft from heavy extractions of ground water, municipal and industrial users in the vicinity of Champaign-Urbana, Ill., agreed to a plan of spreading out the taking of ground water over a greater area. The cooperative arrangement between the users was legalized through the courts to protect each of them, and eliminate competitive exploration of the aquifer. As a result, the decline of water levels has been checked.

State Cooperation

A good example of state cooperation on water problems is the interstate compact. One such compact, entered into by Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia, and West Virginia, is designed primarily to reduce pollution of the Ohio River. Since the creation of the compact, sewage treatment plants have been put in operation or are under construction to serve 75 per cent of the sewered population in the Ohio Valley. This involves 7,500,000 people and more than 800 communities (*5*).

Kentucky has joined the Tennessee River Basin and Water Pollution Control District, an interstate compact to curb contamination of the Tennessee River.

Federal and State Programs

Programs to assist municipalities in water resources development are carried on by most of the state governments. Texas has launched a joint effort with its local units to map watersheds and study beneficial use of water (*5*).

Much of the credit for formation of the new Semitropic Water Storage District, California's largest, goes to the State Department of Water Resources. Its report showing the economic feasibility of the proposal and the repayment ability of the landowners set the stage for the successful election.

The federal government already has launched water programs too attractive for municipal governments to turn down, despite the lingering reluctance to risk centralized control.

Working hand in hand with the United States, Michigan City, Ind., seems now on the threshold of unprecedented industrial expansion. Although Lake Michigan is located at its doorstep, Michigan City has been turning away new industry; because the city lacked supply mains to industrial sites, industries were lost to neighboring cities. Michigan City therefore applied to the US Community Facilities Administration for an advance of funds, interest free, payable from proceeds from the sale of anticipated revenue bonds, and the application was approved.

On a national scale, approximately $650,000,000 was expended for water utility construction in 1957. This clearly indicates that Michigan City is not the only place where the community has outgrown its water utility (*8*).

Portland, Ore., and the US Forest Service signed a 20-year contract whereby the two would cooperate in performing experiments on the Bull Run watershed. Steps now being taken by Portland to meet some of its water supply problems through watershed research are indicative of this progressive approach (*23*).

The Terra Bella Irrigation District of the Central Valley Project, California, received a federal loan of $1,900,000 for construction of an irrigation distribution system. It will serve much of the 11,153 irrigable acres of the district.

In one instance, the Texas Bureau of Reclamation approved a repayment contract with the water users of the Hidalgo and Cameron Counties Water Control and Improvement District No. 9. The contract calls for $10,800,000 to improve existing water works as part of the Lower Rio Grande Rehabilitation Project. Benefits will exceed costs by two to one (*26*).

Many South Dakota cities are short of supply, storage, or transmission line capacity to handle peak loads. A notable exception is Pierre, the capital city.

Through the Missouri River Basin Development Program, the Missouri River will become one series of reservoirs across South Dakota. South Dakota is cooperating with the Corps of Engineers and the USPHS central Missouri River water quality investigation program, and has a network station at Yankton on the Missouri River cooperating with the national basic raw-water quality data program (*22*).

Federal activity in developing water and flood control projects within the various states is growing in scope each year. These projects are vital to the interests of local people and should not be dismissed as "federal."

The Small Reclamation Projects Act provides interest-free loans up to $5,000,000 for local reclamation projects, the prime purpose of which is water conservation for irrigation. The Watershed Protection and Flood Prevention Act implements federal cooperation with state and local agencies in the planning of water protection projects, soil and water conservation, and flood prevention. Municipal lawyers for agricultural communities and irrigation or water districts may advise of these opportunities.

In California, 33 watershed projects were proposed, including the Arroyo Grande Creek Watershed in San Luis

Obispo County, the Upper Chino Basin Watershed in Riverside and San Bernardino Counties, and the Buena Vista Creek Watershed in San Diego County. Clearly, any conservation of water benefits all the towns and cities which tap the watershed for their supply.

Certainly a number of South Dakota communities that have water shortages are counting on such benefits. One project includes the town of Beresford, which has requested water supply storage in the pool development (*22*).

Despite financial boosts from federal and state sources, many desperately needed projects are too expensive for individual districts. The solution lies in union. By uniting their political and financial resources, districts may sponsor and pay the reimbursable costs of projects and share benefits.

Cooperation between districts can be achieved by contract or by creating a parent agency. Ready tools are powers acts by which many states permit public agencies to agree upon the joint exercise of any power common to them and to contribute funds toward an agreed end. The parties are empowered to designate one of themselves, or a specially created board, to act for them all. The representing agency is deemed a separate legal entity.

An alternative lies in the incorporation of a parent district. California has three available acts to do the job. The Municipal Utility District Act provides for union of existing public agencies into one district. Eight now function in the state. Another example is the Metropolitan Water District of Southern California.

A third is the San Diego County Water Authority, for which the general legislation is the County Water Authority Act.

When general statutes will not do, special acts can be written and enacted. Water agencies in many counties combine districts and municipalities by contract.

Whenever a water project is needed in California, a district either already exists or may readily be set up. An amendment passed at the California legislature's 1958 extraordinary session allows an even finer line to be drawn in that it provides that portions of districts may unite upon petition and favorable local vote.

The use of large districts for marketing project services, repayment purposes, or the financing of portions of state projects by local districts was recommended recently by the Assembly subcommittee. It appears that coalitions of districts can be tailored to the measure of any job in water resource development (*27*).

Watershed Control

Of all the rain that falls in the United States, only 20 per cent becomes available for America's heavy demands. The rest is lost by evaporation and transpiration. More is lost by wasteful practices and the failure to adopt scientific methods of conservation. Thus, actually only a very small percentage of the available water after consumptive use has eliminated 80 per cent is used. As the fastest-growing user of water, the municipality is vitally concerned with the development of a greater supply for everyone. Reliable sources of water supply, pollution abatement, flood control, and the maintenance of water tables are the

primary objectives of water development, land management, and conservation in the nation's watersheds.

Because it is a natural operational unit, the watershed is the cornerstone for program planning. It lends itself to multipurpose programs in which flood prevention, water-supply maintenance, pollution control, and outdoor recreational opportunities may all be developed at the same time.

The aim of all watershed control plans is a dependable water supply. Such plans usually call for upstream storage of flood waters and their gradual release as needed, along with conservation measures on the land to minimize excess runoff.

Local watershed districts are backed by the federal soil conservation and forest service program and the Watershed Protection and Flood Prevention Act. From work plans drawn up by the local authorities who apply for federal support, both technical and monetary, overall conservation is being accomplished on a grand scale.

The additional water developed by these programs may be stored underground or in reservoirs. The recharge of underground basins maintains ground water levels and fulfills needs in dry seasons.

Pollution control is a conservation measure because it makes available water which would otherwise be unfit for use.

Action to conserve water may take many forms. For example, the science of cutting consumptive use is making great strides in reducing opportunities for the wholesale losses that occur from evaporation and transpiration. California's brilliant young water engineer, E. F. Dibble, is demonstrating that plant growths which transpire excessively may be replaced with growths that use up far less water. If widely adopted in the watersheds, this botanical approach promises to recover thousands of acre-feet of water that have hitherto been lost. The University of California's progressive agricultural extension service is cooperating in this research.

The water company serving Champaign-Urbana, Ill., recently found it necessary to institute an annual surcharge for water-cooled air-conditioning units when the user fails to make arrangements to reuse water needed for this equipment. Similar action has been taken by the companies serving the Danville and Evanston areas.

The Hanover municipal water utility has planted more than 1,500,000 evergreens on its watershed, which was formerly cultivated farmland. This practice has improved the characteristic of the runoff, and dry-weather flows and total flows have been increased.

Recreational Use

Despite the ever present need to protect water supplies, a bill introduced in the senate or the state of Washington would have opened for public use and access for hunting and fishing all real property in excess of 200 acres owned, leased, or otherwise controlled by a municipal corporation as a watershed or drainage basin. The bill died in committee.

Seattle has followed a watershed protection policy of restricting access into the watershed area. To accomplish this restriction the city has engaged in the acquisition of watershed lands, through purchase, condemnation, and donation.

Seattle has always held that multiple use of watershed areas is a reasonable policy, but only insofar as such uses are compatible with the primary purpose of water supply.

As with the Cedar River watershed, the policy for protection of the Tolt water source will be restricted access to the watershed, with use limited to timber production (*28*).

Most water purveyors favor a policy of closed watershed areas and closed reservoirs of domestic water. With very few exceptions, the policy prevails throughout the United States.

The San Francisco area's East Bay Municipal Utility District insists that reservoirs and watershed areas be closed to the public (*28*). AWWA registered its opposition to legislation permitting or requiring the opening of domestic water supply reservoirs and adjacent lands to recreational use, indicating that: "Control of water supply reservoirs must remain the prerogative of the water purveyor" (*29*).

State Programs

Municipal water suppliers derive substantial benefits from state programs that promote the conservation, protection, and development of the water resources and the study of a basic, long-range water resources policy.

Kentucky's general assembly provided for the creation of "Watershed Conservancy Districts" for the purpose of developing and executing programs relating to any phase of conservation of water (*5*).

Tennessee's new water resources division will explore through public hearings the contrasting viewpoints of all competing users of water and determine their respective needs (*5*).

Minnesota has a water resources board which will establish watershed districts for conservation purposes.

Arkansas' drainage and flood control law, Act 171, establishes watershed improvement districts. Act 327 of 1957 provides for the creation, functioning, and maintenance of districts to construct levee and drainage facilities in cooperation with the federal government.

Object of Arkansas' new Water Conservation Act is the conservation, storage and use of surface water. The Arkansas commission includes seven members, including one employed in the operation of a municipal water distributing system (*5*).

Louisiana's Sabine Authority includes the watershed of the Sabine River and portions of the parishes of DeSoto, Sabine, Vernon, Beauregard, Calcasieu, and Cameron. It is given broad and extensive powers concerning the waters of the Sabine River Valley, including flood control, navigation, irrigation, water supply, drainage, land reclamation, soil conservation, and the development of hydroelectric power. The authority may issue up to $50,000,000 in bonds, payable out of the revenue derived through its operation.

Improper drainage can lead to soil erosion problems, a dropping of the ground water table, loss of otherwise available surface water supplies, destruction of forests and wildlife and the impairment of navigation. Probably the most difficult problem in connection with drainage and flood control is to determine how to remove the surplus water from where it is not needed and at the same time prevent as much of it as possible from escaping into the ocean or being lost through

evaporation. The object, of course, is to prevent loss of life and property damage and yet keep the water available for use when it is needed. Another important phase of drainage is the reclamation of overflowed lands. Already millions of acres of formerly useless lands have been drained and converted into income producing lands (*5*).

Flood and levee drainage control is the aim of Louisiana's law creating the new Coushatta–Red River Levee District. Florida provides for drainage and flood control in substantially the same manner as does Louisiana.

Restrictions on Use

Great savings of water are possible through the regulation of air-conditioning operations, a comparatively new draft on the supply. So serious is the consumption that many cities no longer allow excessive use of water in air-conditioning units. Absolute limits of provisions that allow only that consumption needed to compensate for losses by evaporation, windage, and similar effects are common.

An excellent statement of reasons for regulation is that embodied in the Newton, Kan., ordinance (*30*):

WHEREAS, the operation of water-cooled air-conditioning equipment for changing the temperature or humidity of the air has produced such an extreme demand on the city's water system and an excessive load on the sewage plant of the city of Newton; and

WHEREAS, the uncontrolled, unconserved use of water as a coolant in air-conditioning systems is a waste of a natural resource; and

WHEREAS, it is not economically feasible to provide sufficient sewage and plant facilities to service the additional load created by uncontrolled, water-cooled . . . air-conditioning systems; and

WHEREAS, in the best interests of the public and its water and sewage systems it becomes necessary to regulate the use of water for such purposes and to require the conservation of water and the elimination of unnecessary wastes;

Now, therefore, be it ordained . . .

Evaporation Control

The search for chemical techniques to reduce loss of water by evaporation is being watched with great interest. Success has been reported with hexadecanol, which forms a monomolecular surface film—that is, an invisible shield between the water and the surrounding air. Its effect is less positive on larger bodies of water than on smaller surfaces.

According to Q. L. Florey, physicist at the Bureau of Reclamation's Denver office:

In the arid West, reservoir evaporation reduction is vitally important. One western city alone loses each year approximately 11,000 acre-ft, or 3.6 bil gal, of water through evaporation—enough water to supply, on the average, the full municipal needs of 44,000 persons for a year.

In the western states, losses due to evaporation from water surfaces average 11,500,000 acre-ft a year—which is underscored by the fact that prices of irrigation water in the West range from $1 to $40 an acre-foot, and that the cost of municipal reservoir water varies from $10 to $80 an acre-foot. . . . If only a small percentage of the evaporation can be reduced from the West's many reservoirs, potentially millions upon millions of gallons of precious water can be conserved.

The reclamation bureau is now evaluating the effect of monomolecular layers on Lake Hefner of the Oklahoma City, Okla., municipal water supply system—a 2,500-acre reservoir.

Russell G. Dressler, chemical process consultant for San Antonio, has analyzed the difficulty of keeping the monomolecular films intact. He has offered new methods to apply a film continuously by mixing the chemical with water and pumping the solution through orifices in a distribution line in amounts adapted to local weather conditions, which can affect the film's stability.

Both hexadecanol and octadecanol have been cleared by USPHS on the ground that no hazard to health is anticipated in their use. Preliminary results from the Bureau of Reclamation studies show the films have no adverse effect on fish, aquatic plants, or wild fowl.

Cloud Seeding

Another unique method of increasing the water supply in localized areas is cloud seeding. Artificial rainfall has already been produced with some success, but it also has raised involved legal problems. The major question is who owns the clouds. Ultimately, it may be necessary to regulate rainmaking rules of nationwide application and by international treaty. Now is the time for water lawyers to measure the scope of such regulations and pave the way for a workable plan of administration.

Experiments on producing rain by seeding clouds with dry ice or silver iodide show spotty results. Some say they are no more promising today than they were a decade ago. The Council of the American Meteorological Society was not optimistic in the spring of 1958. It reported (*31*): "Present knowledge of atmospheric processes offers no real basis for belief that the weather or climate of a large portion of the country can be significantly modified by cloud seeding."

H. T. Orville, chairman of the Advisory Committee on Weather Control, established by Congress in 1953, is more optimistic. He reports (*32*):

> The advisory committee has established, with a satisfactory degree of probability, that cloud-seeding operations on the windward slopes of the Pacific Coast States during the cooler and moist winter and spring months have produced significant overall average increases in precipitation from the storms seeded over that which would have been expected without cloud seeding.
>
> At this time the advisory committee's studies do not enable it to apply these conclusions either to the results of artificial precipitation increasing in other portions of the Nation or to the possibilities of hail and lightning suppression.

Saline-Water Conversion

The sea is the logical source of water for the future. During and since World War II, experimental work in saline conversion has received impetus under both private and public auspices. Demineralizing equipment is in actual large-scale operation in certain water-scarce areas of the world, and produces about 15 mgd. The largest distillation plant, at Aruba, Netherlands Antilles, produces 2.7 mgd. Plant and operating costs are reported to be extremely high, and the operations are on a small scale in comparison to what would be required in California. Cheap energy, perhaps from nuclear sources, would facilitate the saline-water conversion process. But it is apparent that some years may elapse before nuclear energy becomes economically competitive with conventional power (*25*).

Pioneers in the conversion of sea water have come up with brilliant results in the laboratory, but they have

been unable to make the processes economically feasible. The cheapest process to date would cost $1.50 per 1,000 gal, which is 30 times more than cities now spend to treat the lowest grades of water (*31*). Twenty years ago it cost about $50 per 1,000 gal, and plants may now be designed to produce water for $1.00 or even less.

On the federal level, efforts are constantly being made to assist individuals, industries, and state and local governments in solving their water problems. In connection with long-range planning, Congress in 1952 passed an act which states (*5*):

> In view of the acute shortage of water in the arid areas of the nation and elsewhere and the excessive use of underground waters throughout the nation, it is the policy of the Congress to provide for the development of practicable low-cost means of producing from sea water, or from other saline waters, water of a quality suitable for agriculture, industrial, municipal and other beneficial consumptive uses on a scale sufficient to determine the feasibility of the development of such production and distribution on a large-scale basis, for the purpose of conserving and increasing the water resources of the nation.

The little city of Coalinga in Fresno County, Calif., has installed the first municipal water desalting plant in the United States.* The city council unanimously approved plans to proceed with the project to furnish the city's separately distributed drinking and cooking water.

The city had hauled in fresh water 45 mi by rail since about 1900. In 1957 the city's water freight bill was more than $43,000 for a supply of about 17,000 gpd. The conversion process will provide fresh water at one-seventh of the cost of hauling it in tank cars.

The major saline-water conversion processes are distillation through artificial heat or solar heat, salt separation by the use of membranes, freezing, chemical, or electrical means.

Today at Wrightsville Beach, North Carolina, pilot plants are testing two different distillation processes. At Syracuse, N.Y., a freezing process is being developed.

An electric membrane process is being field-tested in Colorado, and pilot solar distillation plants are being constructed in Florida.

Other processes, entirely new and still in the laboratory stage, are being developed under research contracts with the department by various universities and private research organizations.

Because the expense of the ionic-membrane process is in direct proportion to the salt content, it would cost nearly $5,000 per acre-ft to treat sea water. So it is considered far too expensive to solve Southern California's water shortage.

Even if successful, saline water conversion programs would not be the entire answer to water deficiency problems. Harvey O. Banks, head of the California Department of Water Resources, commenting on the possible use of nuclear energy for sea water conversion and other water development problems, said: "We do not believe that developments in either of these fields will affect in any way the economic or engineering feasibility and need for the Feather River Project insofar as furnishing supplemental water to the Sacramento–San Joaquin valleys and the San Francisco Bay area

* [See p. 38 P&R, April 1959 JOURNAL—Ed.]

is concerned, and work on the project must proceed immediately." According to Banks, reports of a sea water conversion which could produce fresh water at reasonable cost have not been confirmed. To date no process has adequately demonstrated that it could approach competitively the cost of developing a surface water supply.

The most recent pronouncements from scientists who participated in a symposium in Washington, D.C., were (*33*):

1. Processes for converting sea water in large enough quantities to be competitive with surface water are still in the experimental stage.

2. Additional concentrated theoretical and experimental research is necessary.

3. More pilot plant work is required both in the United States and abroad.

Resolutions in both houses of Congress have given impetus to the study of saline-water conversion.

Senator-Elect Clair Engle's bill (HR 10606), intended to supplement the Saline Water Act of 1952 by providing for construction of a large-scale demonstration plant for the production of fresh water from salt water, has been referred to the House Committee on Interior and Insular Affairs.* Engle, before his nomination to the Senate, said:

> It has become pretty clear that conversion of salt or saline water for agricultural purposes will not be feasible for a long time. On the other hand, with respect to municipal and industrial water, it appears that in water-short areas conversion may be competitive with other means of acquiring water in the not too distant future.

*[The bill has since been passed; see p. 35 P&R, January 1959 JOURNAL—Ed.]

References

1. KERBY, H. A. Development of Master Plans to Meet Future Water Needs—Fort Wayne, Ind. *Jour. AWWA,* **50**:203 (Feb. 1958).
2. MORGAN, EDWARD J. Honolulu Water Supply. *Jour. AWWA,* **49**:1412 (Nov. 1957).
3. ANDRYSIAK, RAYMOND S. Water Supply Development Spurs Industrial Growth. *Am. City,* **73**:4:120 (1958).
4. BAUMANN, E. ROBERT & CLEASBY, JOHN L. Effect of 1952–56 Drought on Iowa Impounded Water Supplies. *Jour. AWWA,* **50**:233 (Feb. 1958).
5. Water Problems in the Southeastern States. Research Study No. 11 (Revision of Research Study No. 5). Louisiana Legislative Council (Dec. 1957).
6. Water Supply and Treatment. *Am. City,* **72**:3:29 (1957).
7. WHIRLEY, R. E. Seven Miles to Good Water. *Am. City,* **73**:4:132 (1958).
8. DRAVES, H. J. Development of Master Plans to Meet Future Water Needs—Michigan City, Ind. *Jour. AWWA,* **50**:206 (Feb. 1958).
9. *Western Water News,* **9**:12:8 (1957).
10. *Western Water News,* **10**:9:4 (1958).
11. SHELTON, ROBERT. Voters Favor New Reservoir by 35-to-1 Majority. *Am. City,* **73**:5:134 (1958).
12. *Western Water News,* **10**:3:1 (1958).
13. BERRY, WILLIAM L. & HOWLETT, HERBERT A. Supplemental Water for the San Francisco Area. *Jour. AWWA,* **50**:679 (May 1958).
14. HOPKINS, GEORGE E. New Reservoirs at Tacoma, Wash. *Jour. AWWA,* **50**:97 (Jan. 1958).
15. CASAD, C. CLIFF & CUNNINGHAM, JOHN W. Construction of the Union River Dam at Bremerton, Wash. *Jour. AWWA,* **50**:105 (Jan. 1958).
16. FRANKLIN, WALTER M. Growth of a Water System. *Jour. AWWA,* **50**:201 (Feb. 1958).
17. QUINLAN, ROBERT W. Ample Storage Compensates for Limited Supply. *Am. City,* **73**:6:114 (1958).
18. ORMAN, J. M. As Midland Grows so Does its Water Storage Capacity. *Am. City,* **73**:2:158 (1958).

19. STAPLETON, K. K. Galesburg Goes 30 Miles to Get Plenty of Water. *Am. City*, **73**:5:106 (1958).
20. Griffith Buys Water Wholesale. *Am. City*, **73**:3:117 (1958).
21. BESSE, STANFORD L. Twice as Much Water. *Am. City*, **72**:3:140 (1957).
22. CARL, CHARLES E. Water Supply Developments in South Dakota. *Jour. AWWA*, **50**:213 (Feb. 1958).
23. BETHLAHMY, NEDAVIA & ANDERSON, KENNETH. Watershed Research in Portland, Ore. *Jour. AWWA*, **50**:114 (Jan. 1958).
24. MUEGGE, O. J. Artificial Recharging of Water-Bearing Formations. *Jour. AWWA*, **50**:170 (Feb. 1958).
25. Water Facts for Californians. California Department of Water Resources, Sacramento, Calif. (1958). p. 12.
26. Texas Contract Approved. *Western Water News*, **10**:6:2 (1958).
27. Coalition of Districts Has Great Possibilities. *Western Water News*, **10**:5:1 (1958).
28. PANEL DISCUSSION. Public Access to Lands Surrounding Impounding Reservoirs. *Jour. AWWA*, **49**:1160 (Sep. 1957).
29. AWWA STATEMENT OF POLICY. Recreational Use of Domestic Water Supply Reservoirs. *Jour. AWWA*, **50**:579 (May 1958).
30. COMMITTEE REPORT. Trends in Air-Conditioning Use and Regulation. *Jour. AWWA*, **50**:95 (Jan. 1958).
31. ROBBINS, JOHN. Water—How Fast Can We Waste It? *Atlantic Monthly*, **200**:33 (Jul. 1957).
32. *Western Water News*, **9**:12:7 (1957).
33. *Western Water News*, **10**:1:2 (1958).

Economic Boundaries of Saline Water Conversion

Louis Koenig

A contribution to the Journal by Louis Koenig, Research Consultant, San Antonio, Tex.

SALINE water conversion may be considered an economically feasible alternative to conventional water supply methods in locations where the complete cost for a converted saline supply is less than that for an available fresh water supply. The purpose of this discussion is to explore the economic feasibility of saline water conversion, in terms of its ability to compete in cost with established water supply techniques.

When the saline water conversion program was first set up in the Department of the Interior, certain cost goals were set for conversion. Properly speaking, these were not goals; they were merely targets. The goals, or targets, chosen were the maximum charges being paid for undistributed raw water according to field experiences and information contained in Bureau of Reclamation reports, published water utility operating data, and other sources (*1*). It was hoped that saline water conversion processes would ultimately show lower costs than these, however.

The maximum costs paid in 1952 for undistributed raw water for municipal supply and irrigation, respectively, were $125 and $40 per acre-foot, or 38 and 12 cents per 1,000 gal (*2*). At that time, these cost goals provided a reasonable and sufficient approach, as a first approximation, and served the purpose of guiding researchers and engineers. Six years have passed, however, and it now seems time for a second look and a second approximation. In the intervening 6 years, the costs of most things have risen. The cost of providing water has risen more than most production costs. Adjustment of the 1952 raw-water cost by the *Engineering News-Record* Construction Cost Index (ENR) would change the 38-cent figure to 52 cents per 1,000 gal for ENR = 650 (approximately as in 1955).*

This principle is important in comparisons of saline water conversion costs, because those costs are estimates based on recent technical developments and are usually stated in current dollars. The costs of conventional water supplies, however, are usually quoted in historical dollars, because statistical surveys of the subject are difficult to make.

Beyond this very obvious adjustment, it is necessary to take a closer look at some of the other areas of water costs in which saline water conversion must compete. It is now possible to take a more sophisticated approach to outlining some of the conditions under which saline water conversion can be competitive, although the available data are still very scanty.

* [For an explanation of the cost index used in deriving these figures, see *Engineering News-Record*, **155**:13:89 (Sep. 29, 1955).—Ed.]

Elements of Water Costs

The elements of water costs for the conventional types of municipal and industrial supplies are well known. The costs quoted earlier for raw, undistributed water presumably take into account the costs of intake, storage, and transmission. The important question is: What elements of conventional water costs can saline water conversion influence, and to what extent?

water supply costs that could be changed by saline water conversion are the intake, raw-water storage, transmission, and treatment.

Saline water, when taken from a nearby surface source as an alternative to conventional water from a remote surface source, eliminates transmission. The use of saline water from a constant source, such as ground water or the sea, in place of a fluctuating surface water source, makes raw-

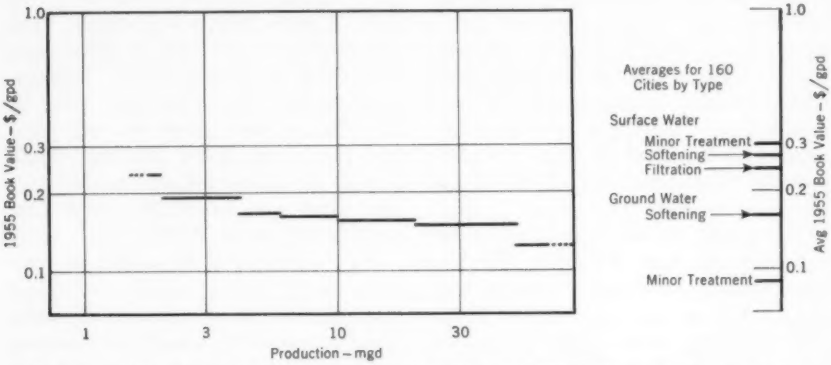


Fig. 1. Median Book Values of Water Facilities for 293 Cities and Averages for System Components of 160 Cities

The median book values include intake, raw-water storage, transmission, and distribution. At the right are shown actual averages for components of both surface and and ground water systems

The use of converted saline water in place of alternative sources could probably influence all cost categories to some degree. For example, the substitution of converted water for an alternative water could possibly decrease the corrosion and maintenance costs in a distribution system. There does not, however, seem to be any major way that substitution of converted saline water could alter the facility or operation cost of a distribution system or distribution storage. The major elements of conventional water storage or impoundment unnecessary. It is also unlikely that converted water from a distillation process would require coagulation, filtration, or disinfection. Some of the conversion processes may require preliminary treatment before conversion, but such treatment is part of the conversion cost, and should be so considered. Conversion by freezing may not require preliminary treatment but may require treatment to remove suspended material and pathogens. Accordingly, conversion processes may

not completely eliminate treatment costs. Certain other combinations of circumstances are possible although not explicitly stated here.

Previous Comparisons

In attempting to understand the cost relationships of various treatment processes quantitatively, one should express investment cost in dollars per unit (gallons per day) of production capacity and water cost in dollars per 1,000 gal.

Comparisons have been made between the investment costs of saline water conversion plants and the book values of conventional water supply systems. Most such comparisons have been quite meaningless, for they have contained major errors that are both favorable and unfavorable to saline water conversion. In the first place, book values are usually stated for the entire water supply and distribution system. Textbook figures commonly place the distribution system investment, including pumping, at 65 per cent of the total investment. This was borne out by the AWWA 1955 quinquennial survey of operating data, which gave a median book value for 311 plants of 62¢/gpd and a median book value for 160 distribution systems of 37¢/gpd (*3*). Although it is not quite accurate to compare figures on two different sets of plants, the distribution system investment given by the survey was 72.5 per cent of the total plant investment. For illustrative purposes one may say that the average distribution system represents roughly 70 per cent of the total plant value. This leaves 30 per cent of the total plant value for intake, storage, transmission, and treatment.

In Fig. 1 the 1955 book values of intake, raw-water storage, transmission, and treatment facilities in 293 cities, calculated as 30 per cent of the book value of the total plant, are plotted against the production rate (*3*). The median total plant book value for all 293 cities is 59¢/gpd, and 30 per cent of this gives 18¢/gpd for the intake, raw-water storage, transmission, and treatment portions. At the right of the graph are some actual cost data (not calculated by the 30 per cent factor) for book values of the four components in 160 cities arranged by supply and treatment types.

The adjustment so far appears extremely unfavorable for saline water conversion because it reduces an initial book value of 59¢/gpd for conventional supply, used in some earlier comparisons, to one of only 18¢/gpd. This adjustment is more than compensated for, however, by the too easily overlooked fact that the 59¢/gpd is a depreciated value based on costs of 20–30 years ago. On the basis of a 40-year straight-line depreciation and using the ENR indexes it can be shown that for every dollar of the 1958 book value of a plant built in 1948, the replacement cost would be $2. For a plant built in 1938 it would be $6 and for one built in 1928 it would be $12. Thus, the average investment cost for intake, raw-water storage, transmission, and treatment would not be 18¢/gpd, but several times that amount at ENR = 650. In confirmation of this, a recent estimate (*4*) places the 1957 average investment for a complete plant at $1.59/gpd. The uncertainties and variability of the statistical approach make it only a qualitative guide at best, however.

Break-Even Equation for Conversion

In spite of the many variables, it is nevertheless possible to consider, in

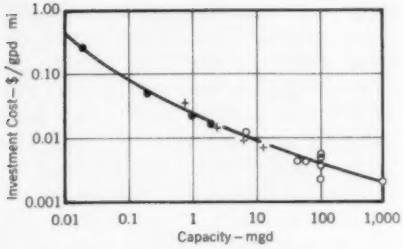


Fig. 2. Pipeline Investment Costs

Open circles represent actual water pipeline costs; solid circles are the author's estimates; crosses are actual oil pipeline costs.

general terms, those costs of conventional water system components and operation which would be eliminated by saline water conversion. On the basis of generalized cost estimates, it is possible to set up the following equation for the economic advantage of saline water conversion (expressed in dollars per unit production):

$$T + RS + \Delta F - W - SWC = E \ldots (1)$$

where T is the investment or operating cost of transmission; RS is the investment or operating cost of raw-water storage or impoundment; ΔF is the difference between investment or operating cost of treatment with and without saline water conversion; W is the cost of wells or lifting (assuming that the cost of the alternative intake facility is negligible); SWC is the investment or operating cost of saline water conversion; and E is the economic advantage of saline water conversion over conventional supply.

When E is positive there is an economic advantage in using saline water conversion, and, when E is negative, conventional sources are economically preferable.

When $E = 0$ there is no economic advantage in either method, and Eq 1 becomes:

$$T + RS + \Delta F - W = SWC_{be} \ldots . (2)$$

where SWC_{be} is the break-even cost of saline water conversion.

The break-even cost of saline water conversion is the maximum investment or operating cost that a saline water conversion process may reach and still compete economically with a conventional process under the given conditions.

In order to use the relationships of Eq 1 and 2, it is necessary to determine generalized costs for those components of conventional water supply which may be eliminated by saline water conversion.

Conveyance Costs

In a previous study (*5*), the author showed that it was possible to correlate pipeline investment costs and conveyance costs with fair accuracy over

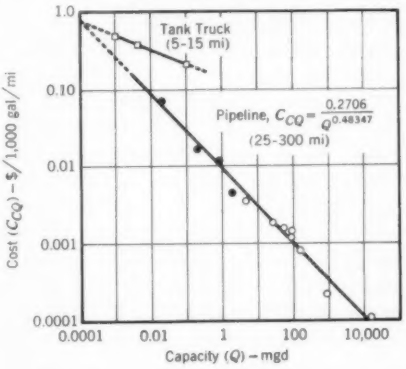


Fig. 3. Transmission Cost Curve

The cost curve for truck transmission is included to facilitate comparisons of saline water conversion costs with the cost of emergency supply.

wide ranges. Figure 2 shows the pipeline investment costs derived from that study. The open circles are actual figures for water, the crosses are actual figures for oil, and the solid circles are the author's cost estimates for specific capacities. The figure for 1,000 mgd refers to the Colorado Aqueduct. It fixed costs as 40-year amortization with 4 per cent interest, 1 per cent for taxes, and 1 per cent for insurance.

Using investment costs as a basis for amortization, interest, taxes, and insurance, and adding estimates based on actual experience for pump station and pipeline repairs, pump energy, and

TABLE 1

Cost of Conveying Water by Pipeline

Description	Capacity, Q, *mgd*	Cost per 1,000 gal* $/mi	Weighted Average Length *mi*	Remarks	Reference
Author's estimates	0.02	0.0695			5
	0.2	0.0170			5
	1.000	0.0107			5
	2.000	0.00465			5
Existing industrial pipeline	5.050	0.0036	25		5
Estimates for Municipal Authority of the Upper Colorado, Tex.	30.24	0.00181	40.5	53 per cent load factor	5
	57.00	0.00135	40.5	100 per cent load factor	5
Estimates for Guadalupe Canyon line, Tex.	100.00	0.00146	18.7		5
	100.00	0.00107	23.3	alternative route	5
Colorado River Aqueduct, 1951–52	175.00	0.000785	267		7, 8
	880.00	0.000220	267	projected to 100 per cent load factor	7, 8
Proposed Gulf Coast Canal	11,800.00	0.000106	269		9, 10

* At ENR = 650.

would be impossible in the space allotted to document the derivation of this point and the one plotted in Fig. 3. Suffice it to say that the author has attempted to arrive at a figure comparable with those of the other examples, which are calculated in conformity with the standard cost-estimating procedure of the Office of Saline Water (*6*)—that is, taking other station costs, it is possible to derive estimated figures for pipeline conveyance costs. Figures derived in this way and other figures based on experienced operating costs are shown in Table 1.

The correlation of the data in Table 1 is shown in Fig. 3. The straight line is not a least-squares line, but, as drawn by eye, the average deviation

of the points from the curve is only 12 per cent, which is a reasonable correlation for parameters covering a 600,000-fold capacity range and a 650-fold range in unit cost. A much more extensive study of pipeline conveyance data is warranted; it would possibly shift the correlation line somewhat and widen the range of data. The data used, however, were taken at random from material available to the author. The only selection was made so as to obtain a fairly uniform distribution over the range of capacity. All data so chosen are shown on the graph.

TABLE 2

Cost of Conveying Water by Tank Truck

Description	Capability *1,000 gpd*	Cost per 1,000 gal* *$/mi*	Avg Distance *mi*	Reference
To stock in central Oregon, 1957	4	0.384	6	11, 12
To stock in Utah, 1957	1	0.44	10	13
Municipal water to Port Isabel, Tex., 1953	100	0.22	15	

* At ENR =650.

Also shown in Fig. 3 and in Table 2 are the costs of conveying water over relatively short distances by tank truck. These data, scanty though they are, are included in order that saline water conversion costs may be compared with the costs of emergency supply.

Raw-Water Storage

Badly needed in water resource economics is a study of the question: What are the investment cost and the operating cost of producing a given firm draft on a reservoir? Indeed badly needed first is a study of whether the answer to such a question is possible at all. The question may be attacked from two points of view, that of engineering and that of hydrology.

From the engineering point of view, the question is: What is the relationship between cost of a reservoir and volume of storage? The answer depends upon the type of reservoir construction and the contour of the valley. To a certain extent these two factors compensate one another; reservoir sites in narrow valleys and canyons usually require high and expensive concrete dams but do not require the purchase of extensive flooded acres, whereas in flat country lower and less expensive earth dams can be utilized, but the terrain requires a large flooded area. Although there must exist extensive data on costs and volumes of reservoirs, very few correlations have been made. An article on the water supply aspects of 233 sites for synthetic-gasoline plants in 1949–51 (*14*) contain some information on costs of a 14-mil gal raw-water storage basin and average costs of 10,000- and 20,000-acre-ft reservoirs. These few bits of data seem to correlate roughly by the "six-tenths rule" and are so used in this study. The figures used in the calculations hereafter are taken from the semilogarithmic correlation given

TABLE 3

Correlation of Storage Costs to Reservoir Capacity

Capacity *mil gal*	Cost of Storage *¢/gal*
10	2.3
100	0.70
1,000	0.22
10,000	0.067

in Table 3. They are about twice as high as 1957 cost data on some sites in Michigan (*15*) and can therefore be taken to represent costs most favorable to saline water conversion.

From the hydrologic point of view the important question is how much storage is required to yield a given firm draft. The answer depends upon the ratio of draft to mean annual flow, as well as to the cumulative flow pattern of the stream—that is, its flow variability. In the synthetic-gasoline plant study the sizes of the impounding reservoirs necessary to provide a firm draft of 13.5 mgd were as given in Table 4 (*14*). The high value of about 600 days gives a measure of the maximum storage capacity required under the most unfavorable conditions, and is roughly confirmed by the capacities of existing reservoirs in arid regions, where saline water conversion is most urgent. These capacities are shown in Table 5 (*16*), in terms of the ratio of usable storage capacity to 90 per cent of the mean daily flow. Because it is assumed that an effort will be made to use as much of the annual flow as possible in areas where the supply is deficient, 90 per cent has been taken as the base. From Table 5 it can be seen that the capacities of reservoirs in the arid regions, where one would hope to utilize 90 per cent of the mean annual flow, are more than 800 days of such firm draft. Similar figures were obtained for Illinois streams and are shown in Table 6 (*17*). Some idea of the magnitude of the variations in required storage for firm drafts of fixed volumes may be obtained from the data in Table 7, which shows the requirements for a firm draft of 250 mgd from the Rock, Fox, and Big Muddy rivers.

TABLE 4

Impoundment Necessary to Provide a Firm Draft of 13.5 mgd

Region	Storage *days*	
	Minimum	Maximum
Appalachians	168	580
Midwest	362	626
Rocky Mountains and Upper Missouri Basin	144	604

TABLE 5

Reservoir Capacity in Arid Regions

Reservoir	Storage* *days*
Lake Mead, Ariz. and Nev.	850
Lake Mead and Lake Mojave	940
Fort Phantom Hill, Tex.	940
Lake Kickapoo, Tex.	1,070
Elephant Butte, N. M.	1,070
Elephant Butte and Caballo, N. M.	1,220
San Carlos, Ariz.	2,720
Lake Henshaw, Calif.	8,850

* Ratio of usable capacity to 90 per cent of mean daily flow.

Because no simple correlation between reservoir size and storage cost has been worked out, in later calculations an upper limit of 1,000 days' storage will be used for all drafts, and the rough unit cost data previously mentioned will be applied. This will for the most part present the most

TABLE 6

Storage Required for Firm Draft of 90 per cent of Mean Annual Flow in Three Illinois Rivers

River	Storage *days*
Big Muddy	1,150
Fox	580
Rock	660

favorable case for saline water conversion, because it will result in the highest raw-water storage cost estimate. Because there is a lack of data on the operating costs of reservoirs, the estimates will be taken simply as fixed costs on the investment.

Treatment

Some idea of the average costs of treatment is provided by AWWA's 1955 survey. Data have been obtained (*3*) for the mean and median water sales revenue per million gallons from 130 plants using minor treatment only, from 158 plants using filtration, and from 88 plants using softening. The difference between those using filtration and those using minor treatment only is about 4 cents per 1,000 gal. The difference for those using softening is higher by 1–2 cents per 1,000 gal.

Treatment costs at the 233 sites investigated for synthetic-fuel plants averaged 4.2 cents per 1,000 gal at a production of 5 mgd. The actual operatting costs for a number of rapid sand filtration plants as well as estimates for the costs of softening are shown in Fig. 4. Investment costs for water treatment plants may be approximated by the data shown in Fig. 5 (*14, 18, 19*).

TABLE 7

Storage Required on Three Illinois Rivers for Firm Draft of 250 mgd

River	Ratio of Draft to Mean Annual Flow *per cent*	Storage *days*	Capacity *mil gal*
Rock	7.5	0	0
Fox	26.8	90	20,000
Big Muddy	58.0	680	670,000

Ground Water Facilities

The cost of a well depends on its depth and diameter, the type of formation, whether or not it is cased or cemented, and other factors. All these factors may vary greatly from place to place. Furthermore, the capacity, or production, of wells in different locations is not necessarily related to the investment cost. The cost of producing water from a well depends upon the cost of power and the necessary lift. The lift may vary considerably, depending on the static water level and the necessary drawdown. The cost of lifting, however, is relatively constant and may be roughly estimated at $5 per acre-ft per 100 ft of lift (*20–22*).

In spite of the variability in well costs, it is possible to make rough estimates of average conditions from some of the scanty statistical material avail-

TABLE 8

Well Construction and Production Costs

Well Type	Avg Production *gpd*	Construction Cost per Well* *$*	Investment Cost* *$/gpd*
Domestic			
Farm	387	814	2.10
Nonfarm	446	697	1.51
Industrial and steam electric	25,800	3,860	0.15
Public Supply	151,000	5,850	0.0388
Irrigation	174,000	3,830	0.022

* At ENR = 650.

able. Table 8 gives the average construction costs of the more than 400,000 wells constructed in 1955, as well as the average daily production of the approximately 14,000,000 wells in operation in the United States in 1955 (*4*). The original data used in compiling Table 8 were annual construction costs in 1954 dollars, the number of wells drilled in 1955, wells in operation during 1955, and 1955 ground water use. These data have been corrected to ENR = 650. The ground water use for domestic and nonfarm wells has been corrected for the small percentage that actually comes from springs instead of wells.

The data in Table 8 are plotted in Fig. 6, giving a generalized correlation of well costs. The curve terminates at a 3-mgd production because this is practically the upper limit for well capacity. It is assumed that at a production of less than 3 mgd the entire production comes from a single well. Thus all productions of more than 3 mgd are calculated at a unit cost of 0.3¢/gpd per 3-mgd well. Production of 3 mgd from twenty 150,000-gpd wells, therefore, would cost ten times as much as from a single well. This assumption is the most favorable one for saline water conversion as it results in the lowest possible cost for wells which are a negative quantity in the break-even equation. Costs of individual wells may vary considerably from these nationwide averages, but, as will be shown, the investment and operating costs of wells are a very small fraction of the magnitudes being compared in this article.

The operating costs of wells consist of the fixed costs calculated in the standard manner, plus the lifting costs taken as 1.54 cents per 1,000 gal per 100 ft of lift. The average lift in the United States is not known, but in these calculations will be arbitrarily taken to be 100 ft.

Break-Even Costs

All the components of the break-even equation as developed above may now be combined as shown on Fig. 7 and 8. Figure 7 shows the break-even investment costs, broken down into their components, and conveyance of 10, 100, and 1,000 mi. It can be seen that treatment and well costs are unimportant items in the equation. The unit investment cost of wells is in the range of 0.3–1.2 per cent of the impoundment, treatment, and well subtotal. The investment cost for treatment is 4–20 per cent of that subtotal, being greater at the higher capabilities.

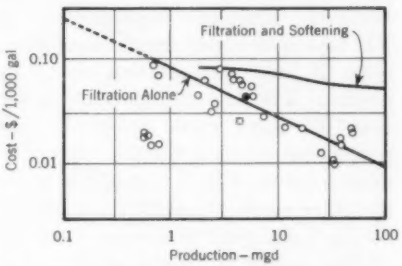


Fig. 4. Operating Costs for Rapid Sand Filtration and Softening

The plots for filtration alone are based on actual data; softening costs are estimates.

The most important of the items replaced by saline water conversion, when a local saline ground water source is used as an alternative to a remote surface source, are the conveyance and impoundment items. It should be remembered that the impoundment cost estimates used are

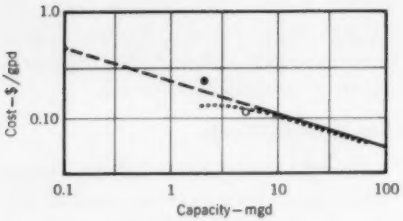


Fig. 5. Investment Costs for Treatment Plants

Sources of data are given in the text.

those most favorable for saline water conversion—that is, those based on 1,000-day storage. Impoundment of 100 days is probably the absolute minimum if any impoundment at all is needed. The cost of impoundment for only 100 days would move the impoundment curve to the position of the dotted line on Fig. 7 and would move the other curves down correspondingly on the logarithmic ordinate. The use of Fig. 7 may be illustrated by a few examples.

For a city of 500,000 people and a demand of approximately 70 mgd, the unit investment cost of a conversion plant using ground water could not exceed 35¢/gpd if it were to compete economically with a conventional surface source 10 mi away and with 1,000-day impoundment. If the alternative source were 100 mi away, the unit investment cost for saline water conversion could be about 74¢/gpd. If, on the other hand, there were no surface source within 1,000 mi, saline water conversion would be preferable even at a unit cost of $4.70/gpd.

For a city of about 10,000 people with 1.5-mgd consumption, a saline water conversion plant operating on ground water could compete even at a cost of $2.20/gpd if the fresh source were 10 mi away and $4.00/gpd if there were no fresh water within 100 mi.

For a city of 2,000 people using approximately 300,000 gpd, saline water conversion plants would be economical at an investment cost of as much as $4.80/gpd if the surface source involved no conveyance at all. Under these conditions and under even the most favorable storage conditions of 100 days, conversion plant costs could exceed $3.50/gpd and still be cheaper than those for conventional plants.

In general, the break-even investment costs (as well as operating costs) for saline water conversion plants depend strongly on the capacity, and capacity is therefore a major determinant of whether a given conversion cost is economical.

Although the break-even investment costs are rather favorable, the operat-

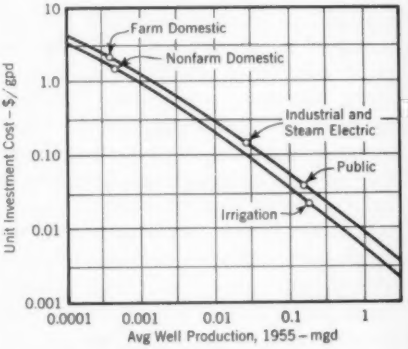


Fig. 6. Well Investment Costs as a Function of Production

The curves terminate at a 3-mgd production because it assumed that this is the upper limit for well capacity, and that a production of less than that amount comes from a single well.

ing costs are less favorable. In Fig. 8 the city of 500,000 population using 70 mgd could transport water 1,000 mi and impound it for 1,000 days at less than the cost of saline water conversion at an operating cost of $1.30 per 1,000 gal. The city of 10,000 using 1.5 mgd could import water from almost 100 mi away and still compete with saline water conversion at $1.00 per 1,000 gal. The village of

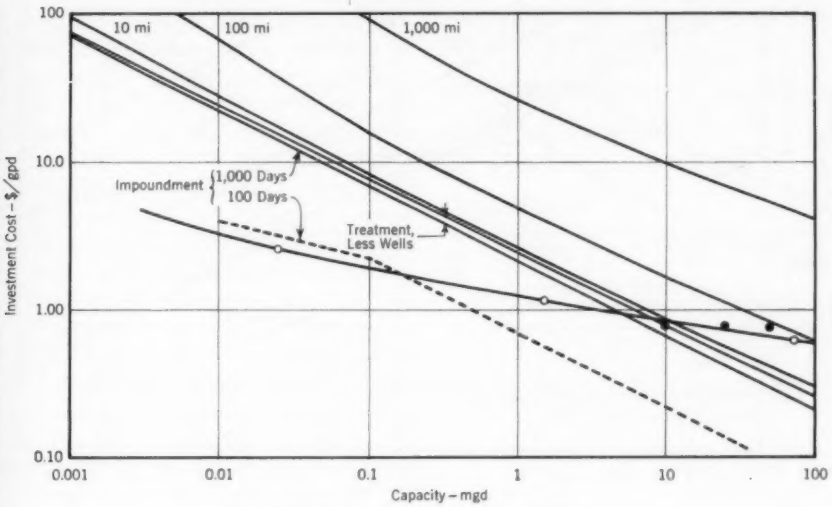


Fig. 7. Break-Even Investment Costs

Sources of data for these curves are given in the text.

2,000 people with a demand of 300,000 gpd could afford to pay $0.80 per 1,000 gal for converted water even if no transportation were involved for the alternative source.

Comparison Without Impoundment

It has been shown that the major costs in the break-even equation, in the case most favorable for saline water conversion, are conveyance and impoundment. In a number of situations, however, impoundment does not enter into the break-even equation. If the remote surface water source is a natural lake, or a river whose minimum recorded flow exceeds the maximum demand, impoundment is unnecessary. If the conventional source is ground water, impoundment is not needed. In the latter event, neither treatment nor well costs would enter into the break-even equation, and only the conveyance cost would remain.

Of course, conditions even less favorable for saline water conversion may be encountered. If the alternative source is fresh ground water and the saline source is a surface water, impoundment enters into the equation to the disadvantage of saline water conversion.

Figure 9 is based upon an intermediate case and shows the break-even investment costs when impoundment is dropped out of the equation. Figure 10 gives the break-even operating costs for the same conditions.

The principles of using the graphs are similar to those previously explained. The comparison is still less favorable. At \$1.00 per 1,000 gal conversion does not compete economically with alternative 100-mi conveyance of as little as 1 mgd.

In Fig. 11 are shown data for costs of conveyance alone. For example, at 1 mgd water can be transmitted 100 mi for \$1.00 per 1,000 gal. At 100 mgd, \$1.00 per 1,000 gal will convey water 1,000 mi.

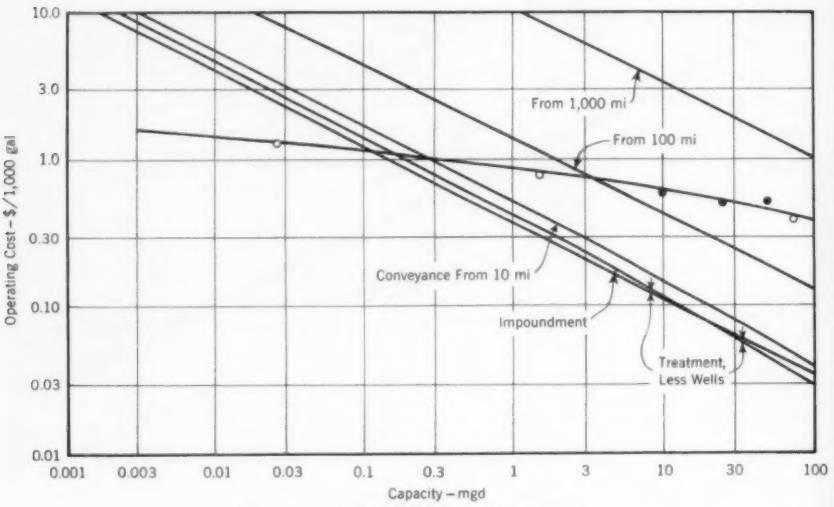


Fig. 8. Break-Even Operating Costs

Sources of data used in compiling these curves are given in the text.

Comparison at Present Estimates

Some of the data shown in the graphs allow a comparison with saline water conversion investment costs estimated for actual plants and processes. The solid circles show estimated investment costs for converting sea water in a seven-effect, long-tube, vertical flash evaporator supplied with steam from a nuclear reactor (*23*) (ENR taken at 750), and the open circles show the estimated costs of converting water of 4,000 ppm salinity by an electrodialysis demineralizer (*24*). The data used in these comparisons were selected only for purposes of illustration and are not to be considered definitive. The author does, however, believe them to be very reliable estimates. Numerous other estimates for these and other conversion processes have appeared in the literature, but, although some of them have been critically evaluated, no definitive study of them all has appeared. The break-even point below which saline water

conversion investment becomes lower than conventional investment under the conditions chosen is at about 10 mgd if no transportation is involved; it is in the neighborhood of 60 mgd if the alternative supply must be transported 100 mi.

In Fig. 8 the circles represent operating costs; under these conditions the position of saline water conversion is even less favorable. Even from brackish sources, it cannot compete with the most favorable combination of alternative sources—even at capabilities as low as 200,000 gpd—if no transportation is involved. If conveyance for 100 mi is involved, conversion is more economical up to 3.5 mgd. For higher capabilities, for example, water could be transported 300 mi from conventional sources under the worst conditions and still be cheaper than conversion. These relations have been rearranged for more convenient use in Fig. 12, in which the economic boundaries of saline water conversion are shown for present-day costs in terms of the three parameters, capacity, distance of alternative source, and days of impoundment. Areas above the line are conditions economical for saline water conversion, and areas below the lines are uneconomical. If a 1,000-day impoundment is required for the alternative source, saline water conversion is at present economical up to a capacity of 150,000 gpd, even if there is no transmission cost for the conventional source. At 1 mgd, saline water conversion is economical if the alternative supply is more than 45 mi away. At 10 mgd, however, the conventional supply must be 180 mi away if saline water conversion is to be economical.

If, on the other hand, no impoundment is involved, the economic boundaries are more restrictive. At 10,000 gpd saline water conversion is economical if the conventional supply is more than 9 mi from the point of consumption, but at 100,000 gpd conversion is uneconomical if there is a conventional source of supply within 90 mi. At 1 mgd, saline water conversion is uneconomical if there is an alternate supply within 200 mi. Boundary curves for other impoundment capacities may be drawn.

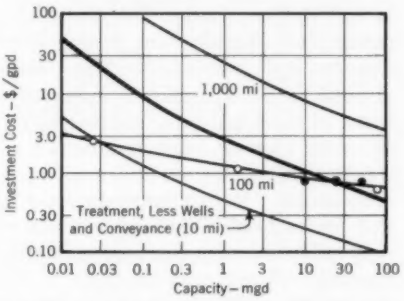


Fig. 9. Break-Even Investment Costs With no Impoundment

Sources of data for these curves are given in the text.

The estimates of conversion costs used here are not to be taken as a definitive statement. They were chosen only to illustrate the method and because they covered a range of capacities. Current estimates of saline water conversion costs are generally reliable, owing, among other things, to the standardized procedure (*6*).

Waste Disposal

Disposal of the unusable waste by-products of saline water conversion is one item of cost not taken into account

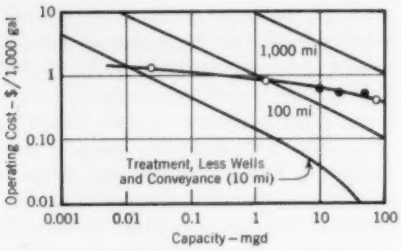


Fig. 10. Break-Even Operating Costs With no Impoundment

Sources of the data for these curves are given in the text.

in the cost estimates, because it depends very heavily on geographical location and conditions. The waste disposal problem created by conversion is not of the usual type; it involves the ultimate disposal (not treatment) of exceptionally large quantities of waste concentrate. It has been shown (*5*) that the costs of all known methods of waste disposal vary exponentially with capacity. Some methods, such as injection, are relatively cheap, but where these cannot be applied alternative methods may easily cost many times as much as conversion itself. Waste disposal costs should, therefore, always be added to conversion costs. Inclusion of waste disposal costs in conversion cost estimates would make necessary the determination of the geographical parameters of any region under study, and they are therefore not included in this discussion. Their inclusion would, however, make saline water conversion less economical than is indicated by the simple capacity-cost relationship.

Supporting Expenditures

In all comparisons of the cost elements of saline water conversion and conventional water supply methods some of the indirect costs are overlooked, and this discussion is no exception.

In the Saline Water Conversion Program certain costs do not appear on any cost sheet or cost estimate, although they are definitely part of the total expenditure made in saline water conversion. These expenditures include the research and development expenditures of the federal and other government agencies, private companies, and other groups, and the studies by government agencies and others to determine the saline water resources of the country. These expenditures, no less than depreciation, power, and other expenses, are all a part of the total cost incurred by society for saline water conversion. Nevertheless, they do not appear on the cost estimates for any given saline water conversion plant.

It is frequently overlooked that conventional fresh-water supplies have these types of indirect costs also; this is particularly important because the

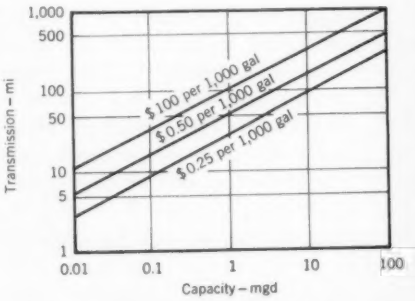


Fig. 11. Distances and Capacities for Transmission at Various Costs

The curves take only conveyance costs into account.

indirect costs for alternate water supply are so much greater than those for saline water conversion. Some of the items that enter into the total cost of water supply but do not appear as the cost of any particular water system or gallon of water are:

1. Theoretical studies of ground water hydrology and hydraulics carried on for scores of years by the state and federal geological surveys, universities, and other groups

2. The basic data collection programs of state and federal surveys and other agencies in stream gaging, water quality studies, ground water studies, and similar fields

3. The activities of the soil conservation service in experimenting with and establishing nationwide water conservation practices

4. Work carried on in specific regions by innumerable local boards, commissions, committees, and foundations

5. Many of the activities of the professional societies such as AWWA, the National Water Well Association, and others in providing information, regulation, and training for water supply purposes.

All of the items listed above are part of the total cost of conventional water supply; together they represent an expenditure in time and money many times the amounts so far spent on behalf of saline water conversion.

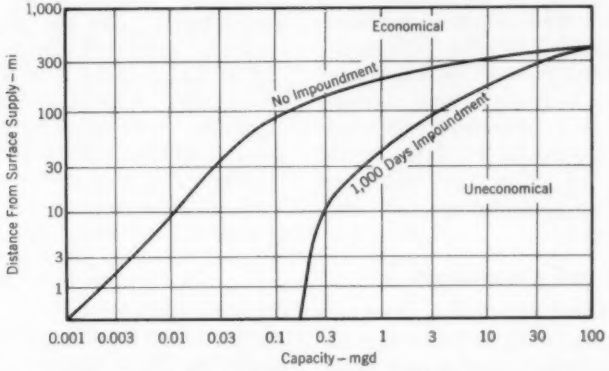


Fig. 12. Boundaries of Conversion in Terms of Capacity, Distance of Alternative Source, and Days of Impoundment

For each curve, areas above that particular curve represent conditions that are economical for saline water conversion; areas below, conversely, are uneconomical for conversion.

Market Study

The data, method, and relationships that have been presented provide the framework for a general market study for saline water conversion. The application of more complete data and actual data for specific locations will make possible the construction of graphs similar to Fig. 12 covering any distance, capacity, and impoundment. Capacity-cost relationships to be anticipated as far ahead as 1970 can be uti-

lized instead of current costs by using alternate source costs adjusted by the ENR cost index extrapolated to 1970. Estimates of the demand at any location in 1970 could be used as a basis for predicting the additional capacity needed by that time. Once this has been done for any location, the boundary relationship in terms of the distance of the source and required impoundment capacity will show which conventional source, if any, may be economically preferable to saline water conversion. The required impoundment capacity of the alternative sources would have to be constructed from basic hydrologic data, because draft-storage relationships (*17*) are not generally available. Data on the availability of saline raw water are already being published and will eventually be complete.

Summary and Conclusions

Saline water conversion influences in a major way only the following components of conventional-supply costs: impoundment, intake, transmission, and treatment.

The sum of the costs of those components eliminated by saline water conversion less those incurred by the saline water source is the "break-even cost for conversion," or the highest cost that conversion can reach and still compete with conventional supply.

The development of generalized investment and operation costs for the components revealed that the unit costs decrease as a fractional exponential function of capacity. These costs are applicable in the break-even equation for any particular case.

For purposes of illustration, an instance most favorable to saline water conversion—where a local saline ground source substitutes for a remote fresh surface source—was chosen and break-even curves were developed. The costs of treatment and intake (wells) were shown to be relatively unimportant compared with impoundment and transmission.

For any fixed saline water conversion cost, conversion is economical at a low production capacity and uneconomical at a high capacity. The lower the conversion cost, the higher the capacity limit at which it becomes uneconomical. As the slope of the curve for estimated actual conversion cost versus capacity is less than that of the curve for break-even cost versus capability, these relations are valid at actual conversion costs as well as at fixed conversion costs.

In full cognizance of the sketchiness of the data, the author has shown that at a water cost of $1.00 per 1,000 gal, the capacity limit is only 200,000 gpd if no transmission is involved, 2 mgd for 100 mi, and 100 mgd for 1,000 mi under the most favorable conditions for conversion. If estimated actual costs for saline water conversion are taken (instead of the arbitrary $1.00 per 1,000 gal) these limits are 0.15 mgd, 3.5 mgd, and 300 mgd, respectively, equivalent to serving populations of 1,000, 23,000, and 2,000,000, respectively.

At estimated actual costs a village of 1,000 would find saline water conversion economical even if the alternative surface source were adjacent to the village. A city of 20,000, however, would do better to use a conventional source if it were available within 90 mi. A city of 200,000 would find conversion uneconomical if the alternative source were within 300 mi. These figures are valid under conditions most

favorable to saline water conversion where a reservoir storage capacity of 1,000 days' firm draft is needed for a conventional supply.

If no impoundment is needed, saline water conversion is uneconomical for a village of 1,000 less than 100 mi from an alternative source; a city of 20,000 less than 250 mi from an alternative source; or a city of 200,000 less than 380 mi from an alternative source.

The importance of waste disposal costs in saline water conversion was mentioned because these costs are not usually taken into account in current cost estimates. The effect of these costs is highly dependent upon geographic and technical variables.

The approach described could be used to construct a general market study for saline water conversion, and the national and regional markets for conversion could be estimated.

Saline water conversion is, under present conditions, most likely to find a market where relatively small production units are involved. It follows that saline water conversion, when once established in a community, would tend to be self-annihilating—that is, the demand for water would grow as converted water increased in availability, the economics of conversion would become less favorable as production increased, and eventually a point would be reached at which it would be cheaper to tap a remote source. Therefore, if saline water conversion is ever to make a major contribution to water supply, conversion research should seek methods which give a greater slope to the capacity-cost curve. The curves for currently favored conversion methods seem to have an anomalously low slope when compared with those for conventional supply techniques.

References

1. Office of Saline Water. Private communication.
2. Third Annual Report, Office of Saline Water (Jan. 1955).
3. Seidel, Harris F. & Baumann, E. Robert. A Statistical Analysis of Water Works Data for 1955. *Jour. AWWA*, **49**:1531 (Dec. 1957).
4. Picton, Walter. Private communication.
5. Koenig, Louis. Disposal of Saline Water Conversion Brines; An Orientation Study. Research & Development Progress Report No. 20, Office of Saline Water, Dept. of the Interior, Washington, D.C. (Jul. 1958).
6. A Standardized Procedure for Estimating Costs of Saline Water Conversion. Office of Saline Water, Dept. of the Interior, Washington, D.C. (Mar. 1956).
7. History and First Annual Report of the Metropolitan Water District of Southern California, Los Angeles, Calif. (1939).
8. Fourteenth Annual Report of the Metropolitan Water District of Southern California, Los Angeles, Calif. (1952).
9. Bureau of Reclamation, Water Supply, and the Texas Economy. Senate Document 57, 83rd Cong 1 (1953).
10. Koenig, Louis. Summary of Conference on Texas Water Problems and Possible Solutions, Jul. 20, 1954. *Bul. Southwest Texas State Teachers College*, **20**:4 (Dec. 1954).
11. Costello, David F. & Driscoll, Richard S. Hauling Water for Range Cattle. Leaflet 419, US Dept. of Agriculture, Washington, D.C. (1957).
12. Driscoll, Richard S. Private communication.
13. Hutchings, Selar S. Hauling Water to Sheep on Western Ranges. Leaflet No. 423, US Dept. of Agriculture, Washington, D.C. (Jan. 1958).
14. Hazen, Richard. How Much Does Industrial Supply Water Cost? *Engineering News-Record*, **150**:8:30 (Feb. 26, 1953).

15. Report on Water Resources Conditions and Uses in the Huron River Basin. Michigan Water Resources Commission, Lansing, Mich. (1957).
16. LANGBEIN, W. B. Water Yield and Reservoir Storage in the United States. Open File Report, US Geological Survey, Washington, D.C. (Sep. 1958).
17. MITCHELL, WILLIAM D. Water Supply Characteristics of Illinois Streams. Illinois Division of Waterways, Springfield, Ill. (1950).
18. HILL, KENNETH V. Treatment Plant Operating Costs. *Jour. AWWA*, **39**:151 (1947).
19. HOWSON, LOUIS R. Economics of Water Softening. *Jour. AWWA*, **43**:253 (1951).
20. ROWHER, CARL. Design and Operation of Small Irrigation Pumping Plants. Circular No. 678, Dept. of Agriculture, Washington, D.C. (1943).
21. The Underground Resources of Arizona. Underground Water Commission of Arizona, Phoenix, Ariz. (1952).
22. Cost of Water for Irrigation on the High Plains. Bulletin 45, Texas Agricultural Experiment Station, Austin, Tex. (1952).
23. Study of the Applicability of Combining Nuclear Reactors With Saline Water Distillation Processes. Research & Development Progress Report No. 19, Office of Saline Water, Dept. of the Interior, Washington, D.C. (1958).
24. Design, Construction, Field Testing, and Cost Analysis of an Experimental Electrodialysis Demineralizer for Brackish Waters. Research & Development Progress Report No. 11, Office of Saline Water, Dept. of the Interior, Washington, D.C. (Dec. 1956).

Discussion

Sheppard T. Powell

Cons. Engr., Sheppard T. Powell & Assocs., Baltimore, Md.

The writer has carefully read Louis Koenig's thoughtful and timely article. The subject has been discussed by others, but rarely has it been so thoroughly treated as in this monograph. The writer is not, however, fully in accord with all of the conclusions reached.

One of the conclusions stated—or, at least, implied—is that saline water plants will be limited to very small capacities. According to the writer's recent experience, however, it is definitely planned to develop large-scale units having capacities of 5–10 mgd in the near future. Successful and economically feasible installations of this type will no doubt be associated and integrated with power generation utilizing the byproduct thermal energy. If such plants are located on the coastline and integrated with heat-producing industries, production costs may be greatly reduced. Plans for such installations are being seriously considered.

In addition to the utilization of byproducts, there is the possibility of reduced investment cost through ingenuity in the design and construction of equipment. There is much room for improvement in design, and, when improvements come, they will be reflected in lower conversion costs. Within the past year new designs have been developed by vendors who have realized the need for a departure from the conventional designs upon which present cost estimates are based.

With the exception of the points discussed above, Koenig's article is both provocative and informative. It contains much useful information and should be of great assistance to those who wish to make comparative cost studies of salt water conversion and remote fresh water supply.

Submersible Pumps as Booster Stations in St. Louis County

Frank E. Dolson

A paper presented on Feb. 5, 1959, at the Indiana Section Meeting, French Lick, Ind., by Frank E. Dolson, Vice-Pres. of Distribution, St. Louis County Water Co., University City, Mo.

THE design and construction of a booster pumping station in a residential neighborhood or in the right of way of a heavily traveled road often challenge the ingenuity of the design engineer. The location of a booster pump should not be determined by the availability of a desirable site, but by hydraulic considerations. Rarely is it possible to find a suitable location for a booster pump, either within or adjacent to the right of way, reasonably close to the spot indicated by the hydraulics of the situation. Often, where there is a coincidence of a favorable land site with the proper hydraulic location, other factors, such as unavailability of the land, zoning restrictions, noise considerations, and unreasonable building requirements, may interfere with and prevent the pumping station installation.

With submersible pumps, the designer is not subject to these limitations. Vertical or horizontal submersible pumps may be installed underground at almost any location within or adjacent to a right of way of a road or street. They are virtually noiseless and tamperproof, require no protection against freezing or malicious damage, and eliminate the need for elaborate building enclosures.

Types of Booster Pumps

The St. Louis County Water Co., because of its 230–sq mi service area and more than 350 ft of topographic relief, has made extensive use of booster pumps. Excluding pumps associated with storage tanks, as many as 14 booster pumps at 11 locations are often used simultaneously in the distribution system on days of peak water usage. In addition, there are 18 pumps at 5 surface storage tanks that pump water from the tanks into the system whenever necessary, and 7 other pumps on two mutual-aid interconnections with the system of another utility. Pumping stations associated with surface tanks and interconnections are equivalent to booster stations because of their similarity of design, and will be treated as such in this article. These pumping installations are used to perform one or more of the following functions: [1] furnish peak-hour requirements by increasing flow rates in arterial or primary mains; [2] increase night flow rates in supply mains to fill balancing storage; [3] transfer water into an isolated pressure district of higher elevation; [4] transfer water to an area normally served by another plant; and [5] pump water from the

storage tanks into the system during periods of heavy usage. Involute centrifugal pumps of the close-coupled type, installed either in an underground vault or aboveground in a building enclosure of residential design, have been used in most instances. Although this type of pump, installed either way, is satisfactory from an operating cost standpoint, it has become more difficult to use.

With underground-vault pump installations, it is not always possible to make the installation at the most desirable site because of the unavailability of adjacent property or because of limitations imposed by road or highway authorities. Noise is a factor to be considered in built-up neighborhoods, and often this consideration results in additional cost, sometimes in the selection of another location. Lack of proper drainage or the expense of providing it may control the selection of the pump site.

Split-case horizontal or close-coupled centrifugal pumps housed in attractively designed buildings are also becoming more difficult to construct at the proper place. In many instances a building site is not available for purchase. Often, if such a site can be purchased, it is necessary to seek and be granted a change in zoning before a pumping station can be constructed. Some zoning boards, as a condition to zoning changes, specify that the proposed building be harmonious architecturally with neighboring structures. Others may go further. It is not unusual for such boards to limit the noise level, require parklike landscaping, or, perhaps, specify more than the normal distance from the property line.

Vertical turbine pumps, driven by conventional vertical motors, installed below ground level in a vault or exposed aboveground, were not overlooked. The steep head-capacity curve of the turbine pump is ideal for booster pumping service, particularly in a growing system where either the suction or discharge head conditions may change from year to year. Even on days of peak pumpage, the steep curve

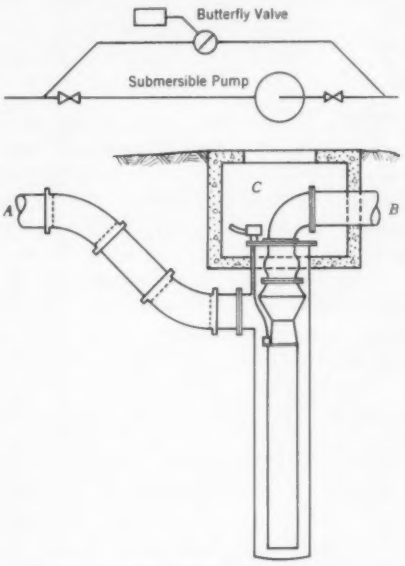


Fig. 1. Des Peres Booster Pump

On top is a schematic diagram of the piping; below, a vertical section of the Des Peres pump. The lettered areas are: A, *20-in. suction pipe;* B, *20-in. discharge pipe;* C, *concrete vault containing the discharge elbow and butterfly valve.*

of the turbine pump is advantageous because of the wide fluctuation between night and day flows in most arterial mains. Although this type of unit is well suited for booster pumping service, it is noisy if the motor is located above ground without enclosure. Vertical turbine pumps cost more than

the conventional involute type of unit, and, if housed, the total cost of installation of such a pump for booster service is disproportionate. Also, more than usual head room must be provided if the pump is enclosed. Although the head-capacity curve is superior, the advantages of the underground vertical turbine over a similarly installed centrifugal pump are not sufficient to justify the cost differential.

Submersible-Pump Characteristics

Submersible-motor turbine pumps have many inherent advantages for booster service over either the vertical turbine or the horizontal centrifugal pump. The two principal advantages are that:

1. They may be installed adjacent to the pipeline within the right of way, thus eliminating the need to purchase adjacent ground or to seek rezoning.
2. They are virtually noiseless in operation, thus reducing objections from neighbors and allowing installation at the proper hydraulic location.

Other advantages of this pump are that it needs no periodic lubrication or adjustment, and needs no protection against freezing or malicious tampering.

On the other hand, submersible motors are not without certain disadvantages: [1] higher initial cost; [2] the possibility of slightly lower motor efficiency; and [3] in the case of motor failure, the necessity for factory instead of local repair. Because the motor in a vertical unit is mounted below the pump, generally a long steel barrel to contain the unit must be sunk into the ground to a considerable depth.

There are three kinds of submersible motors: dry-stator type, wet-stator type, and oil-filled, open-winding type. At the present time, submersible motors of the largest horsepower are of the oil-filled, open-winding type. In these motors, the stator and rotor are immersed in oil, which lubricates all wearing surfaces and protects the ferrous components from corrosion. Oil also helps dissipate heat by circulating through the gap between the rotor and the stator, thereby maintaining uniform motor temperatures. Oil-filled, open-winding motors should be slightly less efficient than the water-filled type because of the viscosity difference of oil and water. Minor efficiency differences, however, are not of much consequence in booster pumping stations where the service requirements are intermittent. It should also be pointed out that some manufacturers of oil-filled, open-winding motors are willing to guarantee efficiencies equal to those offered with wet-stator motors.

Recently, the St. Louis County Water Co. has used the submersible pump whenever it seemed desirable. Four booster pumping stations employing this type of equipment have been constructed. In three of these installations, the vertical turbine pump, having a mercury seal, was used. In the fourth, a horizontal submersible pump was used, mounted within a standard pipe section that only recently has been offered on the market.

The remainder of this article deals with the design and construction of, and operating experience with, one of the vertical submersible booster stations, known as the Des Peres booster pump, and the horizontal submersible unit, identified as the Lucas-Hunt booster pump.

Des Peres Booster Pump

In St. Louis County, the Des Peres booster pump and another unit (Bennett pump) of equal capacity and similar design serve to increase the capac-

ity of two 20-in. mains, which, at the time of construction, were the two principal supply lines to about 20 per cent of the customers of the total system who were located at a distance from the main input pumping station.* Without pumping, the two 20-in. supply lines have a combined capacity of 10–12 mgd on a load day. This is increased to a rate of about 19 mgd or a flow velocity of almost 8 fps when the pumps are operating.

Figure 1 shows a schematic diagram of the piping and a vertical section of the Des Peres pump. This turbine pump, driven by a 200-hp, submersible electric motor, is suspended from the top flange of the vertical steel barrel, which is installed in bypass piping around a 16-in. hydraulically actuated, but electrically piloted, butterfly valve in the main supply line. The pump and motor, which is mounted immediately below, operate submerged in a

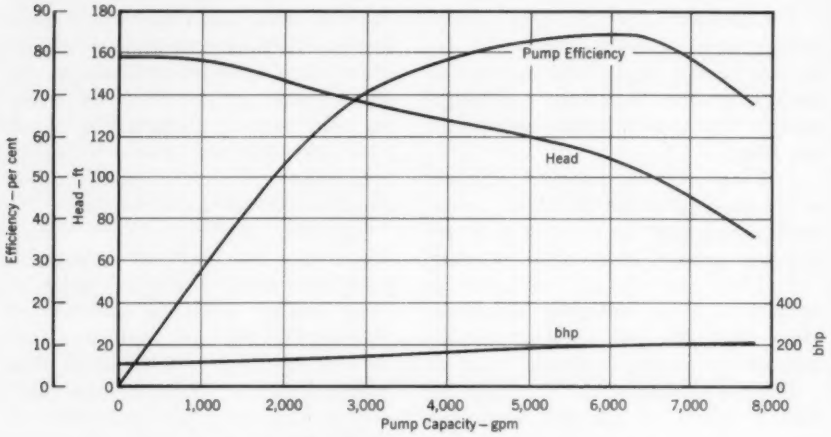


Fig. 2. Characteristic Curves of Des Peres Pump

The pump is driven by a 3-phase, 200-hp, 1,160-rpm, 60-cycle, 440-v submersible motor.

Because these pumps are of extremely high capacity for the size of the pipes and provide service to customers on both the suction and discharge sides, the choice of location for each unit was confined to a limited area. Favorable topography allowed the selection of the high-capacity pumps with the resultant high flow velocities.

flooded steel barrel. The pump unit, at the maximum efficiency point of 84 per cent, has a capacity of 6,300 gpm at 105 ft of head (Fig. 2). The head-capacity curve is such that the pump may be operated over a wide range at little or no sacrifice in efficiency and with no danger of damage from overloading the motor.

Maximum starting torque is required because the butterfly valve is open, thus allowing water to bypass when the pump starts. An auxiliary control on the motor starter energizes

* In a previous article on the progress of controls and instrumentation in St. Louis County, the author discussed the location of pumps and storage tanks (*1*).

a solenoid pilot valve that causes the butterfly valve to close in about 60 sec. Although this method of starting results in a severe torque requirement on the motor and allows bypassing while the valve is closing, the transition to the new pressure gradient and flow conditions is effected without noticeable pressure surges.

The submersible motor is of the oil-filled, open-winding type. Entry of water into the motor, which runs in oil, is prevented by an ingenious mercury seal on the motor shaft. By a balancing tube, water at a pressure equal to that in the steel barrel is introduced into the sealed motor case at some distance below the rotor. The oil floats on the water and completely fills all space between the oil-water interface and the mercury seal. The unbalance of pressure resulting from the difference of specific gravity of the water in the balancing tube and the column of oil above the oil-water interface is counteracted by the mercury deflection in the U-tube construction of the seal. Thermal expansion and contraction of the oil coolant and lubricant is accomplished by free movement of water between the sump and the balance tube.

The receiving barrel was fabricated from $\frac{3}{8}$-in. steel into a cylinder $15\frac{1}{2}$ ft long, with a 32-in. ID, sealed at the bottom by a welded-on, saucer-shaped plate. The upper closure flange, from which the pump is suspended and to which the discharge elbow is attached, was fabricated and supplied by the pump manufacturer. The inside and outside of the tank were protected from corrosion by the application of a suitable coating.

Usually, the steel barrel can be installed in a vertical boring of proper dimensions without much difficulty. A standard pier-drilling rig, having bevel attachments, can drill the receiving hole in a few hours after being set up. The barrel for this unit required a vertical hole 20 ft deep and $4\frac{1}{2}$ ft in diameter. Unfortunately, rock was encountered 5 ft below the surface, which necessitated the use of dynamite and hand excavation methods through 15 ft of rock at an additional cost of approximately $1,000. Sand was used for a cushion on the bottom of the hole and as backfill material.

Controls, either of the weatherproof type or indoor type installed in a weatherproof cabinet, were mounted on a pole located near the pump and adjacent to the right of way of the road. Except for the control enclosures, which are small and not overly conspicuous, the only other evidence of this unit is the concrete top of the vault containing the discharge elbow and butterfly valve.

Except for a faulty design of the power cable entrance into the motor housing, which allowed motor oil to escape into the motor-starter box, and which required removal of the pump to correct, operating experience with this unit has been highly satisfactory. From the operating experience to date, it is reasonable to speculate that with heavy usage, service of the pump at 5–10-year intervals should be sufficient.

One of the most significant features of this pumping station is that it is located within the right of way of a narrow public road not more than 30 ft away from the nearest residence. The unit is so quiet in operation that there is no perceptible noise at a point 10–15 ft away. Its operation has caused no complaint from any customer or road or city official.

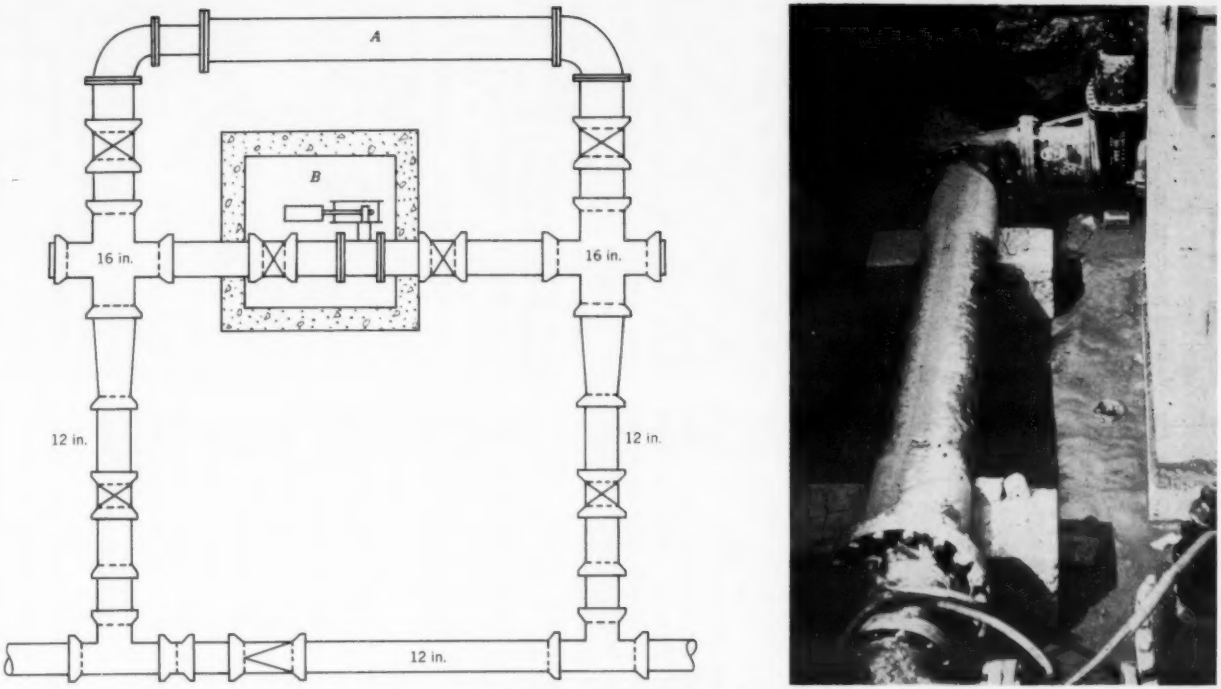


Fig. 3. Piping Layout for Lucas-Hunt Booster Pump

On the left is a top-view diagram of the submersible-piping layout. The horizontal submersible pump within a section of 16-in. pipe is located at A. *The 12-in. butterfly valve is located in the concrete vault,* B. *The photograph on the right shows the section of pipe containing the pump.*

Lucas-Hunt Booster Pump

The horizontal submersible pump has only recently been offered on the market. Its principal advantage over the vertical type is that it is mounted within a section of standard steel pipe. Standard flanges are provided on the ends of this section of pipe. To install the unit, it is merely necessary to insert it into a bypass constructed around the control valve. A vault enclosure is not required, and there is no need to bury the unit deeper than the maximum frost penetration.

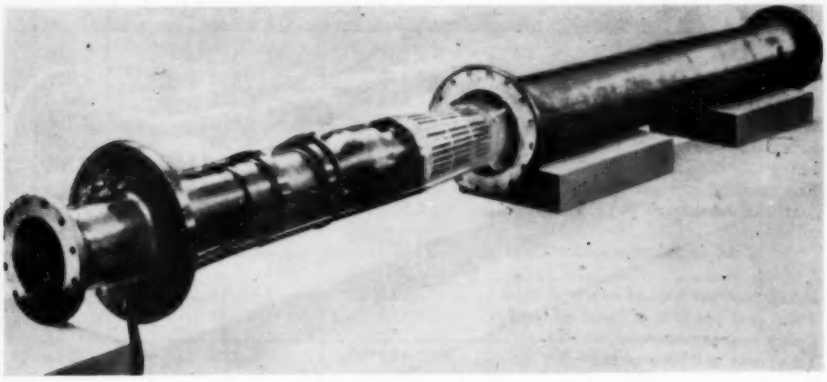


Fig. 4. Lucas-Hunt Pump Prior to Final Assembly

The pump will be centered within the section of 16-in. pipe and held in place by radial supports.

To avoid the expense of purchasing and installing the steel barrel required for the vertical submersible, a horizontal unit was selected for use on an experimental basis for the Lucas-Hunt booster station. At that time there was only one other such unit in service in the United States, and it was considerably smaller in size.

Figure 3 shows a diagram of the submersible-piping layout at the Lucas-Hunt booster pump. Provision has been made for a 16-in. pipe to parallel the existing 12-in. pipe. The head and capacity of the pump were determined based on having the reinforcing main in place. Because of this additional piping, the total cost of the station was more than it would have been otherwise.

The butterfly valve is closed when the pump is operating and open when it is not operating. Normal flow may be in either direction, which makes it necessary that the valve be in the open position when the pump is not running. An auxiliary control on the motor starter instigates a time closure of this valve. As with the Des Peres pump, this method results in maximum starting torque on the submersible motor and allows bypassing during the timed valve closure, but it prevents noticeable pressure surges under starting conditions. Control of the unit is local automatic by time and pressure. Remote control may be added to the circuit whenever it is desirable.

TABLE 1

*Comparative Data for Turbine-Type Submersible Booster Pumps**

Item	Des Peres Pump	Bennett Pump	Lucas-Hunt Pump
Year installed	1955	1955	1957
Motor size—*in.*	16	16	10
Power—*hp*	200	200	75
Velocity—*rpm*	1,160	1,160	1,750
Capacity—*gpm*	6,300	6,300	2,650
Head—*ft*	105	105	84
Efficiency—%	84	84	80
Impeller diam—*in.*	16¼	16¼	10
Discharge diam.—*in.*	18	18	10
Seal	mercury	mercury	mechanical
Installation	vertical	vertical	horizontal
Control	remote automatic	remote automatic	local automatic
	Comparative Costs—$		
Control valve vault	694	527	330
Pump and motor	10,430	10,430	4,029
Steel pump barrel	445	445	—
Butterfly valve, controls, electrical	4,067	4,600	2,796
Pipes and valves	3,132	4,230	3,107
Labor	6,220	4,828	2,168
Engineering, mechanical equipment, trucks, associated payroll	2,912	2,668	2,090
Total installation cost	27,900	27,728	14,520
Pump cost per foot of head—*$/mgd*	11	11	13
Total cost per foot of head—*$/mgd*	29	29	45
Pump cost per horsepower—*$*	52	52	54
Total cost per horsepower—*$*	140	139	194

* All three are 440-v, across-line starting, single-stage pumps.

TABLE 2

Comparative Data for Close-Coupled Booster Pumps in St. Louis County

Station	Year Installed	No. of Pumps*	Head *ft*	Total Capacity *mgd*	Total Power *hp*	Control†	Installation‡	Cost *$/mgd/ft*	Cost *$/hp*
A	1954	1	91	3.6	75	L	U	25	108
B	1954–55	3	64	3.3	45	R	U	58	273
C	1955	2	200	1.08	50	L	U	47	200
D	1955	2	91	7.2	150	M	U	33	143
E	1955	5	91	18.0	375	M	U	24	102
F	1954	4	91	14.4	300	L	B	26	114
G	1954	4	91	14.4	300	L	B	30	130
H	1957	4	91	14.4	300	L	B	35	154

* All pumps are across-line starting and operate on 440 v at 1,750 rpm, except for the pump at Station C, which has a velocity of 3,500 rpm.
† Key: L, local automatic; R, remote automatic; M, manual.
‡ Key: U, underground vault; B, building.

As shown in the photograph (Fig. 3), the section of pipe that contains the pump is merely inserted in and becomes a part of the bypass piping around the control valve. It is buried about 3½ ft underground without enclosure. To remove the unit for any reason would require excavation. The pump selected is of unusual design. It is a 10-in., turbine pump driven by an oil-filled, open-winding submersible motor. A mechanical seal on the motor shaft prevents entry of water into the sealed motor housing, and by the use of a spring-loaded neoprene bag, which also serves as an oil reservoir, the oil pressure is increased above that of the water outside of the motor. Any leakage occasioned by wear of the mechanical seal would result in oil transfer from the motor into the surrounding water. Expansion and contraction of the oil because of temperature change within the motor are compensated for by a change in volume of the neoprene bag. Figure 4 shows the unit in the manufacturer's shop, before assembly within the pipe section.

The pump is centered within a standard section of 16-in. pipe and held firmly in place by radial supports. A 16-in. ring flange is welded on the suction end of the pipe section. Discharge is through a standard 10-in. flange. The unit is designed for horizontal service. Sleeve radial bearings on the pump end of the motor, and the same kind of bearing—supplemented by a Kingsbury-type thrust bearing—at the opposite end of the motor, are used for support. The bearings are lubricated by the motor oil. The pump has a capacity of 2,650 gpm at 80 ft of head, with an efficiency of 80 per cent (Fig. 5). It is driven by a 75-hp, submersible motor.

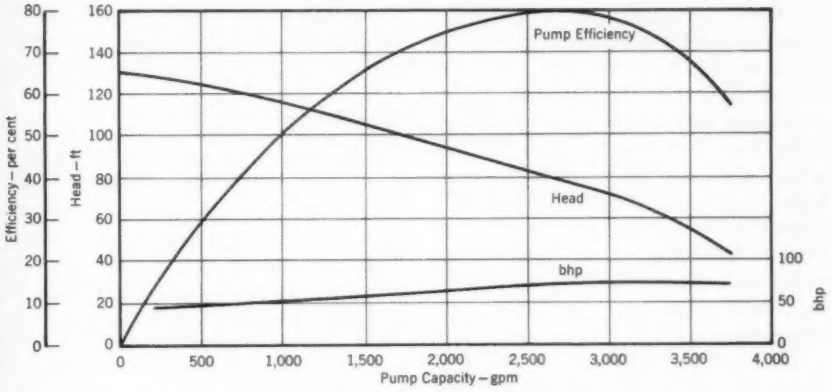


Fig. 5. Characteristic Curves of Lucas-Hunt Pump

The pump is driven by a 3-phase, 75-hp, 1,750-rpm, 60-cycle, 440-v submersible motor.

Performance of this pump has been up to expectation, although after the first 3 months of use, oil began to leak from the power cable into the motor-starter enclosure. This leakage was detected before the oil in the reservoir was depleted and, as a consequence, no damage was done to the motor. Faulty design of the connection between the motor leads and the power

cable within the pump unit was the source of the difficulty. After redesign and correction by the manufacturer, no further trouble was encountered.

There is reason to speculate that the horizontal submersible pump will not require servicing more than once every 5–10 years. If this proves to be true, the pump will be ideal for booster service because it can be buried underground at nearly any location, and it is impossible for a person to detect whether or not the pump is running, even while standing directly over it.

Comparative physical and cost data for both the vertical and horizontal submersible boosters are shown in Table 1. Included in this table are similar data for the Bennett pump, mentioned previously as a companion to the Des Peres pump. Unit cost has been expressed both in dollars per horsepower and in dollars per million gallons per day capacity per foot of head. Selection of a standard-size motor and pump efficiency affects the unit cost expressed as dollars per horsepower.

The costs shown are actual. If trended to reflect the difference in the price and wage levels between the years of construction, there would be closer conformity of the unit costs. It should also be noted that these unit costs apply only to specific installations and are not applicable to other situations where materials, controls, and construction problems may differ. For example, the horizontal submersible pump at Lucas-Hunt has a higher unit cost than either of the vertical units. Yet, under comparable circumstances, the total installation cost of the horizontal pump should be equal to or less than that of the vertical type.

Table 2 shows comparative physical and cost data for typical conventional boosters where the close-coupled centrifugal pump has been used. Land cost, where involved, has been excluded in arriving at the unit cost because of the difficulty of fair apportionment. It will be observed that the unit cost of the larger installations of this type, taking into consideration the building enclosure, but excluding the cost of land, is less than the unit cost of large vertical submersibles. Cost studies made of the two types indicate lack of uniformity in this respect, and show that other factors, such as land, building requirements, and noise suppression, often may reverse the picture.

Conclusions

Submersible pumps are well suited for booster pumping service and can be used at locations where it is impossible to construct conventional stations. They are inconspicuous after installation, require no elaborate landscaping, and are virtually noiseless when operating. Because of these factors, such pumps, in addition to performing required service, are a useful public relations tool to reduce public complaint and opposition to the utility. They can be installed at reasonable cost, and the service factor between maintenance should prove to be satisfactory. The horizontal unit has such interesting potentialities for this kind of service that its performance will be carefully observed.

Reference

1. Dolson, Frank E. & Quade, Hadley A. Progress of Controls and Instrumentation at St. Louis. *Jour. AWWA*, **51**:83 (Jan. 1959).

Storage Tank Repair With Plastics

Claud R. Erickson

A contribution to the Journal by Claud R. Erickson, Mech. Engr., Board of Water & Light, Lansing, Mich.

IN 1922, a 50,000-gal, riveted, overhead storage tank was installed at the Moores Park Electric Generating Station for the Board of Water and Light, Lansing, Mich. The tank was made of ¼-in. steel plate. It has a diameter of 19 ft and a hemispherical bottom. The height to the overflow is 85 ft. The total inside area in contact with water is 1,620 sq ft.

Originally a tank for condensate storage, after 3 years it was used to store river water. In 1936, a cold-process lime and zeolite water-conditioning plant was installed at the Moores Park station, and the overhead tank was used to even the fluctuations due to central steam-heating demands. It has served this purpose since 1936.

This tank has had unusually severe service conditions: the water has been near oxygen saturation, the temperature of the water varies from 34° to 95°F, depending upon the season, and the pH has been from 9 to 10.

Maintenance

Maintenance of this tank included an interior painting every 4 to 5 years. Many types of coatings were applied, and with each painting, up-to-date knowledge of metal protection was utilized. During the past 15 years, however, corrosion had proceeded at so rapid a rate that many small holes had formed throughout the tank, and patch welding became necessary. In 1956, test holes were drilled, and it was determined that 35 per cent of the thickness of the tank wall had been lost to corrosion. Because of excellent maintenance practices, the outside of the tank and the supporting structure were in good condition (Fig. 1).

Costs of Repair

Studies were made of alternate methods of putting the tank in good condition for continuous operation. Among the methods studied were: painting with asphaltic or bituminous materials, silicones, and epoxy and

TABLE 1

Costs of Repairing 50,000-gal Overhead Storage Tank

Item	Cost *dollars*
Sandblasting sand, 12½ tons @ $20	250
Labor for sandblasting, 160 hr	480
Fiber glass fabric, 500 sq yd @ $0.65	325
Epoxy resin, 135 gal or 1,300 lb @ $1.37/lb	1,780
Solvent,* 6 gal @ $2	12
Miscellaneous brushes, roller	75
Application of plastic, 160 hr	480
	3,402
Overhead	
20 per cent on labor ($960)	192
10 per cent on material ($2,442)	244
7.5 per cent for engineering and supervision	255
Total Cost	4,093

* Cellosolve; a product of Union Carbide Chemicals Co., New York, N.Y.

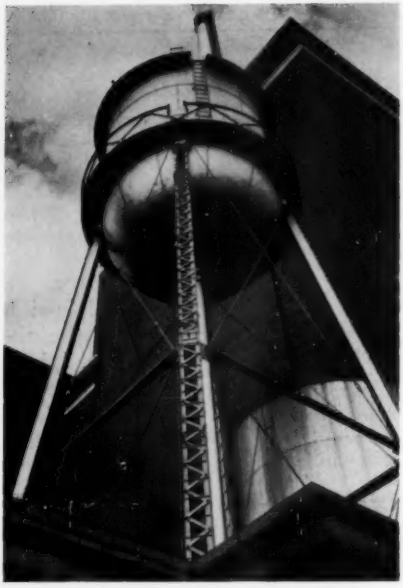


Fig. 1. Overhead Storage Tank

The tank has a 19-ft diameter; it is 85 ft from foundation to overflow.

polyester resins (plastics); metalizing with zinc, shotcrete, and guniting (using either standard or lightweight aggregates); and using thixotropic laminating material, with glass fabric as a reinforcing material. The estimated cost of these methods of interior tank protection varied from $3,500 to $6,000. A study of their advantages and disadvantages indicated that the longer-lasting repair would result from the use of an epoxy resin reinforced with glass fabric. The costs of making the repair on a tank of this capacity are shown in Table 1. A new tank on the present columns would cost $21,000.

Technique of Repair

The sandblasting must be thorough, reaching the bare metal, and where any large holes are exposed, a $\frac{3}{16}$-in. steel patch should be welded to the tank. It is not necessary to plug the pinholes that result from sandblasting.

Fig. 2. First Coat of Epoxy Resin

The left portion of the illustration shows the raw metal. The use of rollers to apply later coats, in which the resin was heavily pigmented, proved to be impractical, and calcimine brushes were used instead.

Fig. 3. First Layer of Fiber Glass Fabric

The glass cloth is applied while the pigmented resin is still tacky.

The first coat of epoxy resin was applied to the entire interior surface (Fig. 2). The second coat and those coats applied between the layers of glass fiber were heavily pigmented to assist in filling the voids in the glass fibers. Setting time for this pigmented material was shorter than for the clear resin, and application with rollers proved to be impractical. Therefore, inexpensive calcimine brushes were used and discarded as the material began to set in them.

The second coat, consisting of pigmented resins, was applied to small areas, approximately 4×5 ft. While this coat was still tacky, the fiber glass fabric was applied (Fig. 3). This fabric can be obtained in standard widths of 38, 44, 50, and 60 in., with 125–250 sq yd per roll. When applied, the glass fabric should overlap previous layers by 2–3 in. on all sides.

After the first layer of glass fabric was imbedded in place, another coat of pigmented resin was applied to saturate the fabric thoroughly. Then the second layer of glass fabric was applied.

The final coat was of clear resin to provide a smooth, dense surface impervious to water (Fig. 4). The composition of this final coat was modified by using a polyamide hardener rather than the standard polyamine hardener. This modification resulted in a final surface even more resistant to water absorption than that from the usual epoxy resins. The total thickness of the lining thus applied should

Fig. 4. Final Coat of Resin

This coat of clear resin provides a surface impervious to water.

be approximately $\frac{1}{8}$ in. where two layers of glass fabric are used.

While the resin is being applied, ventilation is needed to protect the workmen from the slightly toxic vapors that are given off during the time of reaction between the resin and the hardener. After the reaction is complete, this vapor is no longer given off and all toxic conditions cease. Brushing or rolling on the epoxy resin will result in as good a job as spraying. Furthermore, if a spray application is used, more ventilation is needed.

In old tanks that require repairs because of corrosion, most of the damage is at the water line. When such a condition exists, it is recommended that an additional layer or two of glass fabric be installed for a distance of 3 ft above and below the point of maximum corrosion.

The glass fabric used on the hemispherical bottom may be cut into spherical triangular pieces or applied as rectangular pieces. When applied as rectangles, there will be more overlapping, and additional glass fabric and resin will be necessary, but this added cost will be offset by the saving in labor. The fiber glass fabric used in the repair weighed 9.7 oz/sq yd.

Properties of Resins Used

There are two types of resins that can be used for this repair work: polyester and epoxy. Both are thermosetting. The setting of polyester resin is accomplished by catalytic action, and the time of setting may be varied by the amount of catalyst used. Resistance of polyester resin to penetration of water is not good, neither is its adhesion to steel; but adhesion to woods, except oak, is excellent. The cost of this resin is relatively low, \$0.53 per pound (\$5.10 per gallon). It is used primarily for coating boats.

The setting of epoxy resin is accomplished by the cross-linking of molecules owing to the action of a hardener. Its setting time in a mixing pot is 20 min; when the resin is in thin sections, the time increases to 60–90 min. Its adhesion to steel is excellent, its permeability to water practically nil. Both resins form a good bond with glass fabric, but epoxy resin is not

TABLE 2

Physical and Chemical Properties of Epoxy Resin

Property	Amount
Density—*lb/cu ft*	72
Compressive strength—*psi yield point*	18,000
Tensile strength—*psi*	33,000
Flexural strength—*psi*	35,000
Hardness, Rockwell M Scale	92
Flammability	slow
Heat resistance—*°F/5 min*	300
Heat resistance, continuous—*°F*	200
Thermal conductivity—*Btu/hr/ft/°F*	0.12
Thermal coefficient of linear expansion—*in./in./°F*	0.000037
Effect of acids	none*
Effect of weak alkalies	none
Effect of strong alkalies	slight
Viscosity at 75° F—*poises* (Brookfield viscometer)	6

* Except for strong oxidizing acids.

sufficiently adhesive to support glass fabric reinforcement on a vertical surface. Normal practice is to support the fabric at the top of the surface with temporary hooks and roll it into the resin as the resin becomes tacky. This procedure presented no serious problem.

Epoxy resin is insoluble in water and therefore presents no contamination problem. When reinforced with glass fabric inside the tank, it should last for about 10 years without requiring surface treatment. Regular inspections, however, should be made, and it may become necessary to apply a coat of clear resin at 5-year intervals. The surface coating may not be effective if water has permeated the glass fabric, causing it to expand more than its 880 sq ft/lb. This condition will be apparent during inspection by a slight crystalline appearance of the surface, and may be eliminated by recoating. The cost of thixotropic (thickened) and pigmented (colored white) epoxy resin is $1.37 per pound ($13.15 per gallon). It weighs 9.6 lb/gal.

This resin has dimensional stability. Up to 100°F, the steel of the tank and the resin have practically the same coefficient of expansion. Reinforcing the resin with glass fabric increases its strength four times. The repaired tank had nearly the structural strength of the original installation.

Some of the physical and chemical properties of the epoxy resin are shown in Table 2.

Preferably, repair work of this kind should be done during the summer months, when the outside temperature is 60°F or above. Care should be taken to clean skin that has been in contact with the resin using thinner and soap and water, because workmen who are allergic to it may develop a slight case of dermatitis. This effect of the resin, however, is not seriously detrimental to its useful applications.

Conclusion

A study of twelve different methods of repairing a 50,000-gal, riveted, overhead storage tank indicated that the use of reinforced epoxy resins would be the most economical one. This method of repair is expected to result in minimum maintenance for the next 20 years and can be used not only to repair an old tank but also to protect a new one, thereby reducing the need for maintenance and prolonging the useful life of the tank.

Discussion

Loring E. Tabor

Specification Engr., Dept. of Water & Power, Los Angeles, Calif.

Plastics for the repair of a water storage tank, as described in this practical and interesting article, can be used as long as the old tank has sufficient strength to support the lining.

For some time, the Los Angeles Department of Water and Power has experimented with various coatings. Several epoxy coating materials have been tested and found to vary considerably. In general, those materials with a short mixing-pot life seem to produce the stronger and more impermeable coatings. The materials with a longer pot life, and those to which solvents have been added, produce a softer coating that is more permeable. One epoxy resin coating with a pot life of approximately 10 min produces a very hard but slightly flexible coat-

ing that is almost completely impervious. If this coating were applied approximately 10 mils thick over the fabric reinforcement, it is estimated that it could last more than 50 years.

It is well to check epoxy resin coatings with a high-voltage spark holiday detector. A 5-mil coating of epoxy resin will not be penetrated by a 20,000-v spark. By the use of the process described in the article, the life of the tank can be extended, it is believed, to a point where it would fail from defects other than those from the epoxy resin lining.

At the present time, the Los Angeles Department of Water and Power specifies that epoxy resin coatings be applied to all ferrous surfaces in contact with the water in its large, rotary cone valves, spherical valves, and pressure-regulating valves. Results have shown that this material resists cavitation as well as corrosion. Of course, its application does not require a fabric reinforcement, because its adhesion to sandblasted ferrous surfaces is excellent.

A very long life is expected from these epoxy resin coatings, because the hard, high impact–resistant, catalytically cured type is being used.

Correction

The article "Radiological Health Training for Supply and Pollution Control Personnel," by Dade W. Moeller, Donald A. Pecsok, and Harry P. Kramer (April 1959 JOURNAL, Vol. 51, pp. 423–430), contained two editorial errors. On p. 430, in col. 1, lines 11–13, the words "of an analytical reference service is conducted" should read "sponsors or conducts an analytical reference service." In the last paragraph of the article, p. 430, the parenthetical reference to "Table 2" should read "Table 1."

Fifty Years of Advancement in the Knowledge of Water Substance

Arthur M. Buswell

A paper presented on Mar. 12, 1959, at the Illinois Section Meeting, Chicago, Ill., by Arthur M. Buswell, Research Prof. of Chemistry, Univ. of Florida, Gainesville, Fla.

FROM the contents of various bibliographies, it appears that 90–95 per cent of what is known about water substance has been reported within the past 50 years. The extent of this knowledge can be gaged roughly by the fact that *Chemical Abstracts* now lists about 1,000 articles a year on the subject of water, exclusive of those articles dealing with purification, and even the review articles cite hundreds of titles. A rigorous, completely documented report on the advances in knowledge of water substance in the last 50 years would reach enormous proportions, far beyond the limits of this article. Therefore, only the chemical properties of water and those physical properties intimately related to its chemistry will be discussed.

New Laboratory Tools

The rapid advance in knowledge of water is largely the result of the development of new tools. In general, the tremendous advances in electrical instruments have made possible the measurement of properties of water with a precision that makes feasible the detection of suspected but hitherto unmeasurable effects. As an example, the dielectric constant of water can now be measured with an accuracy that makes it possible to observe the effect of solutes, temperature, and pressure. Spectroscopy or spectrophotometry has been known for many years, but its extension to the infrared, where water has its fundamental absorption band, was a great boost to water chemistry. X-ray has shown the arrangement of atoms; microwaves and radar have also been of use. One of the latest instruments is the nuclear magnetic resonance detector, probably the first instrument to detect a molecular difference between liquid water and ice. A recent report (*1*) describes its use in following the chemical reaction of water during the setting of concrete. Physical properties will be discussed first, because they serve as a base for the study of the chemical properties.

Physical Properties

The physical properties of water known 50 years ago, included the temperature-density diagram with a maximum at 4°C. The knowledge of water, current at that time, was well discussed in a Faraday symposium (*2*) and summarized as follows:

> . . . as a result of this discussion, one will soon find even in the textbooks that while ice is trihydrol $(H_2O)_3$ and steam monohydrol (H_2O), liquid water is mostly dihydrol $(H_2O)_2$, with some trihydrol in it near the freezing point and a little monohydrol near the boiling point.

In an extension of the Lewis-Langmuir theory of valence, Latimer

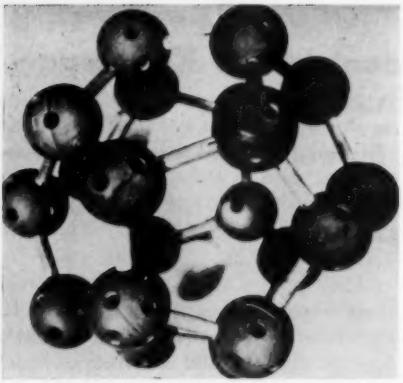


Fig. 1. Model of the Molecular Structure of Water

The model is a pentagonal dodecahedron. Each ball represents one water molecule, or else one oxygen atom with each stick representing a hydrogen bond.

and Rodebush (*3*) suggested the H-bond concept, a hydrogen atom between two pairs of electrons serving as a valence mechanism, which has had wide application in explaining a variety of chemical structures. Applied to water, this concept suggested the obvious mechanisms of molecular association. If water molecules are associated by hydrogen bonds, there seems no reason to limit the number of molecules in a group, as suggested before, to two or three, or to any other number.

By the mid-1930's it was demonstrated by infrared, x-ray, and other experimental techniques that in ice each HOH unit was associated through H bonding with four other HOH units. In liquid water the HOH units are irregularly but more closely packed, each HOH unit being associated with five or more other HOH units and the association extending throughout the entire sample. In other words, a mass of water, be it a drop or an ocean, is one molecule, its size depending on the size of the vessel or container in which it is retained. The HOH units are not stationary, however, as in a solid crystal, but have kinetic motion, the rate of which depends on the temperature. In this magma of associated H-bonded HOH units, float a varying number of "icebergs," composed of HOH units arranged through H bonds to give them the crystal structure of ice. The number of HOH units in these clumps is probably many times more than the three units mentioned before. These structures, shown in Fig. 1, are much more open than the structure of the liquid, and the density is less. As water warms from 0°C, the number of these icebergs decreases, and the density increases. From 4°C, the density of water decreases with higher temperature, because the expansion of liquid water is greater than the con-

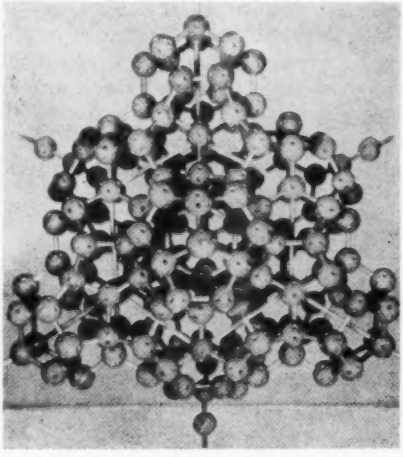


Fig. 2. Pentagonal-Dodecahedral Diamond Lattice

The longer sticks in this model pass through dodecahedrons and are attached at each end to tetrahedral water molecules. The structure is the result of a new method of packing dodecahedrons, forming a cubic cell.

traction that results from the melting of the remaining icebergs.

Gas Hydrates

Icelike clumps of HOH units that are stable up to 60°C have been observed to form around certain nonpolar gas molecules. Methane hydrate (*4*) is interesting because it is stable at temperatures well above the freezing point of water and because it was troublesome in clogging natural-gas pipelines. This problem was solved by drying the gas before transmission. These gas hydrates have been extensively studied by Rodebush and associates and have added greatly to the knowledge of water substance. It was found that the HOH units were arranged in ice-type groups that had hollow spaces in which the gas molecules were held, a new idea in the concept of solubility. It might be called "space" solubility, as contrasted to either polar solubility or a mere mixture of molecules. The probable structure is discussed in some detail by Claussen (*5*):

The study in this laboratory of possible icelike hydrate structures by means of molecular models, 2 [now 10] years ago, revealed the desirability of fitting a regular pentagonal dodecahedral water structure (Fig. 1) into some kind of a crystalline lattice because: [1] this structure would give a large enough space for the smaller hydrating molecules; [2] the water molecules in this structure would be in about the same energy state as those of ordinary ice, since the pentagonal angle (108 deg) is very close to the tetrahedral angle (109.5 deg); and [3] the number of water molecules belonging to a single hole would be five, close to the hydrating number for the smaller inert gases. In the figure, each ball represents one water molecule, or each ball may represent an oxygen atom with each stick being a hydrogen bond. It was apparent, after a little study, that the regular pentagonal dodecahedron would not pack in any kind of a crystalline lattice.

A manner of packing these dodecahedra [12 faces] was recently discovered, which consisted of, first, slightly deforming the regular dodecahedron, so that the angles around two opposite molecules were exactly tetrahedral, then superimposing these two tetrahedral points on pairs of carbon atoms in a diamond-type lattice. The amazing result was the packing to form a cubic cell (Fig. 2). The longer sticks in this model pass through dodecahedra and are attached at each end to tetrahedral water molecules;

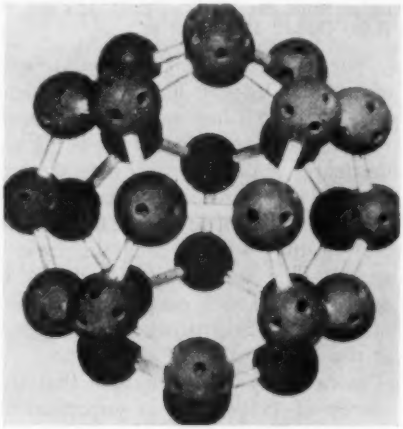


Fig. 3. Hexakaidecahedron

This model contains four hexagonal and twelve pentagonal faces.

they do not represent bonds; however, they are directly comparable to the bonds in the diamond lattice.

Out of this diamond-pentagonal dodecahedral lattice has come a new hole or void, a hexakaidecahedron (16-hedron) containing four hexagonal and twelve pentagonal faces (Fig. 3). This structure contains a larger void space than the dodecahedron, thereby offering the possibility that large hydrating molecules can get into only the large holes, while smaller molecules might get into all the holes. It is apparent that one might ex-

pect two hydrating numbers on the basis of this structure, in agreement with the known facts.

Some data on the unit cubic cell as shown in Fig. 2 are:

Total number of balls (water molecules) in model, 242
Number of molecules in unit cell, 136
Number of pentagonal dodecahedrons, 16
Number of hexakaidecahedrons, 8
Hypothetical hydrating numbers: for large molecules, $^{136}/_{8}$ or 17; for small molecules, $^{136}/_{24}$, or $5^{2}/_{3}$.
Examples of the small and large molecule hydrates are: Small molecules: CH_4 7.18 H_2O; C_2H_6 8.25 H_2O; C_3H_8 5.8 H_2O; SO_2 6.1 H_2O; Cl_2 5.9 H_2O; Br_2 7.9 H_2O. Large molecules: C_3H_8 17.95 H_2O; CH_3I 17 H_2O; C_2H_5Cl 16 H_2O.

The importance of the mechanisms of freezing, long an important problem in biology (*6*), has suddenly increased with the advent of frozen foods. Furthermore, a project was recently announced by space scientists to study the feasibility of freezing a man, so that he may survive long flights into space. The study of gas hydrates is one angle of attack on the mechanisms of freezing. Such work is in progress at the University of Florida.

It can only be noted here that the theory of H bonding is important in explaining the relationship of liquid-water structure to its dielectric constant, change in viscosity with temperature and pressure, change in specific heat with temperature, change in refractive index with pressure, and a number of other less commonly encountered properties.

Chemical Properties

According to the known chemistry 50 years ago, water was supposed to be composed of two elements—that is, pure substances with indivisible atoms. They were hydrogen and oxygen, found in the weight ratio * of 1.008 to 8, and a volume ratio of 2:1. The formula was written H_2O, hydrogen being assigned a valence of one and oxygen a valence of two.

The ionization theory of Arrhenius was just reaching the textbooks 50 years ago and was still controversial in some quarters. From this theory it was understood that water was a polar liquid and that mineral salts, acids, and alkalis, when dissolved in it, were separated into positively and negatively charged ions. Some authors, reluctant to accept the evidence of electrically charged ions, still wrote them with a dot and a prime; for example, $H^{\cdot}$ and OH'.

It was in 1908 that Sorenson (*7*), and in 1909 that Washburn (*8*), independently showed by simple algebraic equations that because the reaction of an acid and a base consisted in the combination of H^+ and OH^- to form H_2O, the strength or intensity of both acidity and alkalinity could be designated by either the H^+ concentration or the OH^- concentration. Sorenson chose to express these values in terms of the H^+ ion, and because in his mathematical derivation he let 10^p equal $[H^{\cdot}]$ and 10^q equal $[OH']$, he chose the symbol $P_{[H\cdot]}$ for the value $\log 1/[H^{\cdot}]$. Because this symbol required a special character, the printers rebelled, and by the mid-1920's "pH" came into general use. Furthermore, because from this theorem $H^+ \times OH^-$ is a constant, K_W was chosen for this value, which numerically is equal to 1×10^{-14} at 25°C (*9*).

This new concept of an intensity factor, as contrasted to a capacity factor for alkalinity and acidity in water, clarified a great number of chemical problems. Of those in the field of water treatment should be mentioned the adjustment of the reaction of culture media for coliform bacteria determination, the pH control of alum treat-

* Established by W. A. Noyes, professor, Univ. of Illinois.

ment and softening, and certain phases of corrosion. *Illinois Water Survey Bulletin* No. 22 (*10*) summarizes much of the early work on treatment, emphasizing that water itself is involved in the chemical reactions of water treatment. And not of least importance is the conclusion that water is both an acid and a base. Because the concentration of H_2O (monohydrol) is small, it probably is a strong acid and base.

The next advance in knowledge of water, as mentioned earlier, was the paper by Latimer and Rodebush (*3*) on an extension of the Lewis-Langmuir theory of valence that proposed the H bond. This valence mechanism not only explains association but also serves as an explanation of certain chemical reactions. The theory, now generally accepted, considers hydrogen as divalent and oxygen as tetravalent. It explains many of the problems connected with conductivity of solutions, solubility, and absorption spectra. It was further discussed in connection with the physical properties of water.

The startling announcements in six articles (*11–16*) published from 1932 to 1934, reporting the isotopes of hydrogen and oxygen, showed conclusively that "water isn't H_2O." These articles were reviewed by the author in 1938 (*17*). The following is a quotation from his article:

"Water," therefore, instead of being H_2O, contains the imposing list of substances, 33 in number, which are shown in Table 1.

Of these substances the deuterium or D compounds (D_2O) are found present to the extent of about 200 ppm [now estimated at 150], and the O^{18} compounds perhaps as high as 1,000 ppm. Since O^{18} is very similar to ordinary oxygen (O^{16}), it is difficult to separate and study and is not regarded as particularly important at present. The O^{17} and the tritium (T) compounds are present in exceedingly small amounts. For the present we may dismiss the O^{17}, O^{18}, and T forms of water from further consideration. Since D_2O differs both chemically and physically from H_2O and is found in appreciable amounts, it is attracting wide interest.

Heavy water boils at a little higher temperature than H_2O. This property permits its concentration by fractional distillation. The still columns required are 30–40 ft in height, and the process of concentration is very slow. Since deuterium ions require a higher voltage for their electrolytic separation than do hydrogen ions, the solution used for the electrolytic production of hydrogen becomes enriched in D_2O. This is the basis of the process by which most of the D_2O is produced at present.

TABLE 1

Types of "Water" Molecules and Ions

Formula	Mol. Wt.	Formula	Mol. Wt.
H_2O	18	HTO^{17}	21
HDO	19	DTO^{17}	22
D_2O	20*	T_2O^{17}	23
HTO	20	H_2O^{18}	20
DTO	21	HDO^{18}	21
T_2O	22	D_2O^{18}	22
H_2O^{17}	19	HTO^{18}	22
HDO^{17}	20	DTO^{18}	23
D_2O^{17}	21	T_2O^{18}	24

Ions

H^+	OH^-	$O^{17}H^-$	$O^{18}H^-$	T^+
OT^-	$O^{17}T^-$	$O^{18}T^-$	D^+	OD^-
$O^{17}D^-$	$O^{18}D^-$	O^{--}	O^{17--}	O^{18--}

* Heavy water.

The physiological properties of D_2O are surprising. Heavy water appears to be entirely inert and useless as far as its effect on plants and animals has been studied. Seeds will not sprout in D_2O, and rats given only D_2O to drink will die of thirst. There are no poisonous effects of D_2O, since if H_2O is given soon enough, rats which have had only

D_2O will recover and will show no ill aftereffects. . . .

Recently O^{19} has been reported, but since it has a half-life of only 29 sec, it is not found in natural waters.

Heavy water, D_2O, has found an important use as a moderator in nuclear reactors. It is also widely used in tracing the course of organic and biological reactions in which active hydrogen is involved. Deuterium will replace active hydrogen, and the original location of the active hydrogen in the molecule can then be determined. Tritium was scarcely mentioned in the review article 21 years ago (*17*), but it is now commercially available as a tracer. It is formed in nature in the outer atmosphere by the action of cosmic rays and is radioactive with a half-life of 12.5 years; hence, it reverts to hydrogen with time, and disappears unless replenished from the atmosphere. It has been used to date well waters to determine the recency of recharge. Samples from a well in Urbana-Champaign, Ill., showed no detectable tritium, indicating that the water was at least 50 years old and had not come from recent recharge.

References

1. KAWACHI, KIYOHIKO; MURAKAMI, MIYUKI; & HIRAHARA, EIJI. The Hydration and Hardening of Cement: The Nuclear Magnetic Resonance Absorption of Water Molecules in Cement. *Bul. Fac. Eng., Hiroshima Univ.*, **4**:95 (1955).
2. WALKER, JAMES. Symposium—The Constitution of Water. *Trans. Faraday Soc.*, **6**:71 (1910).
3. LATIMER, W. M. & RODEBUSH, W. H. Polarity and Ionization From the Standpoint of the Lewis Theory of Valence. *J. Am. Chem. Soc.*, **42**:1419 (1920).
4. DEATON, W. M. & FROST, E. M. Gas Hydrates and Their Relation to the Operation of Natural Gas Pipe Lines. *US Bur. Mines Monographs*, No. 8 (1949).
5. CLAUSSEN, W. E. Suggested Structures of Water in Inert Gas Hydrates. *J. Chem. Phys.*, **19**:259 (1949).
6. MERYMAN, H. T. Mechanics of Freezing in Living Cells and Tissues. *Science*, **124**:515 (1956).
7. SORENSON, S. P. L. Studies of Enzymes: On the Measurement and Importance of Enzyme Concentrations. *Compt. Rend. Lab. Carlsberg* (Fr.), **8**:1 (1909–10).
8. WASHBURN, E. W. The Theory and Practice of the Iodometric Determination of Arsenious Acid. *J. Am. Chem. Soc.*, **30**:31 (1908).
9. WASHBURN, E. W. The Significance of the Term Alkalinity in Water Analysis, and the Determination of Alkalinity by Means of Indicators. *Proc. Illinois Water Supply Assn.*, **2**:93 (1910).
10. GREENFIELD, R. E., ET AL. Investigations of Chemical Reactions Involved in Water Purification. *Illinois State Water Survey Bul.*, No. 22 (1926).
11. UREY, H. C.; BRICKWEDDE, F. G.; & MURPHY, G. M. A Hydrogen Isotope of Mass 2. *Phys. Rev.*, **39**:164, 864 (1932).
12. UREY, H. C.; BRICKWEDDE, F. G.; & MURPHY, G. M. The Hydrogen Isotope of Mass 2 and Its Concentration. *Phys. Rev.*, **40**:1 (1932).
13. UREY, H. C. & TEAL, G. K. The Hydrogen Isotope of Mass 2. *Rev. Mod. Physics*, **7**:34 (1935).
14. GIAUQUE, W. F. & JOHNSTON, H. L. An Isotope of Oxygen, Mass 17, in the Earth's Atmosphere. *J. Am. Chem. Soc.*, **51**:3528 (1929).
15. OLIPHANT, M. L.; HARTECH, P.; & RUTHERFORD, E. Transmutation Effects Observed With Heavy Hydrogen. *Nature*, **133**:413 (1934).
16. OLIPHANT, M. L.; HARTECH, P.; & RUTHERFORD, E. Transmutation Effects Observed With Heavy Hydrogen. *Proc. Roy. Soc.* (*London*), **A–144**:692 (1934).
17. BUSWELL, A. M. Water Isn't H_2O. *Jour. AWWA*, **30**:1433 (Sept. 1938).

Electrical Conductivity and the Stability of Colloids

Willy G. Woxholt

A contribution to the Journal by Willy G. Woxholt, Chief Chemist, Rand Water Board, Transvaal, Union of South Africa.

THERE have been a great many published articles on coagulation of suspended solids to render turbid water supplies suitable for domestic and industrial purposes. These articles have dealt with the relative merits of the various coagulants, singly and mixed, with or without coagulant aids, and the preferred order of their application. Innumerable tables have been given of results of laboratory jar tests on waters from hundreds of sources of widely varying quality. Much useful information is to be gained through careful study of these data.

Occasionally truly classic works have appeared in the scientific and trade journals devoted to the water supply profession. Some of these have dealt with the nature and stability of the colloids, and have described methods of measuring their electrical properties, mobilities, rate of dispersion and base-exchange capacities. Such works have been eagerly received by those interested in the clarification of turbid waters and in the study of colloids generally.

It is, however, a little disappointing that so relatively little emphasis has been placed on the importance of the specific electrical conductivity of the dispersion medium.

Electrical Conductivity and Coagulation

If Helmholtz' double-layer theory (or Gouy's and Freundlich's diffuse double-layer modification of it) is valid, the electrokinetic zeta (ζ) potential must be accepted as a measure of the stability of a colloid. In the equation,

$$\zeta = \frac{4\pi ed}{D},$$

the dielectric constant D is proportional to the specific electrical conductivity of the dispersion medium and may, with suitable (cheap and easily obtainable) equipment, be determined in a matter of seconds.

Although the electric charge e and the thickness d of the double layer vary with colloids in waters from different sources, the specific electrical conductivity (and, therefore, the dielectric constant) can be measured with great speed and accuracy. It can therefore be considered the most important and reliable factor determining the "relative zeta potential," and, consequently, the ease or difficulty with which the suspension can be coagulated.

The product $4\pi ed$ may be large or small, but cannot affect the relation-

ship between the zeta potential and the specific electrical conductivity. Therefore, as the electrical conductivity of the dispersion medium is increased, the zeta potential drops until it eventually reaches zero, or the isoelectric point, and the suspension coagulates.

It is interesting to compare turbid Mississippi River water, which has an electrical conductivity of 400 micromhos per cubic centimeter at 20°C, with water of the Vaal River (Union of South Africa), which has a specific electrical conductivity of 120 micromhos per cubic centimeter upstream of its highly saline tributaries, the Klip and the Suikerbosrand rivers (both of which drain the mining areas of the Witwatersrand). It is significant that more than 50 per cent of the suspended solids in the Mississippi supply settle out in 2 hr, whereas less than 1 per cent settles out in Vaal River water after 24 hr. It may be argued that this difference in settleability has little to do with the difference in electrical conductivity; that it is merely a function of the particle size or the rate of dispersion of the suspended solids; and that Stokes' Law determines the rate of settling.

In samples of Vaal River water collected several miles below the confluences of Vaal and its saline tributaries (usually very clear water in which about 80 per cent of the salinity consists of calcium and magnesium sulfates), the electrical conductivity may vary from as little as 80 to more than 1,000 μmhos per cubic centimeter at 20°C. It has been observed that the suspended solids present in this water of lower electrolyte content scatter far more light (the suspended solids are more finely dispersed) per unit mass than do suspended solids in water of higher electrolyte content.

The surface phenomena of adsorption and base exchange on clays are, as with natural greensands and synthetic resins, as much a function of particle size (exposed surface area per unit mass) as of type. Thus, for a clay with known base-exchange properties, the exchange capacity is greater per unit mass for fine than for coarse suspensions.

Many years' experience in the clarification of the water of the Vaal River has convinced the author that the most important single factor determining the stability of the suspended solids is the specific electrical conductivity. *Coagulant doses required for effective coagulation, regardless of which particular coagulant is used, vary inversely with the electrical conductivity.*

TABLE 1

Analysis of Dried Suspended Solids in Vaal River Water

Item	Amount *per cent*
Loss on ignition	15.7
SiO_2	46.9
Al_2O_3	25.2
Fe_2O_3	7.9
CaO	1.6
MgO	1.6
Total found	98.9

To obtain further proof of the relationship between electrical conductivity of the water and the zeta potential which determines the stability of the suspended solids, a series of thermal coagulation tests were carried out on samples of Vaal River water with varying electrolyte content.

It may be appropriate, at this stage, to give some details of the suspended solids carried in the Vaal River water at the point of sampling. A typical analysis of a dried (at 110°C) sample

of the suspended solids (obtained by thermal coagulation) is given in Table 1.

The high ferric oxide content in the suspended solids is attributed partly to the presence of waste pickling acids from steel works, but differential thermal and x-ray diffraction analysis showed the mineral Illite to be strong, with traces of Muscovite, Halloysite, and Kaolinite.

A particle size analysis of a sample of suspended solids in river water of electrical conductivity of 180 micromhos per cubic centimeter at 20°C revealed diameters of $2\text{–}50 \times 10^{-6}$ mm.

Thermal Coagulation

Thermal coagulation has, to the author's knowledge, never been explicitly explained, but it is suggested that it is caused by the increase in ionic mobility at higher temperatures. Because electrical conductivity is a direct function of ionic mobility, it is thought that the destabilization and eventual coagulation of colloids are caused by the increase in electrical conductivity at higher temperatures. Unfortunately, apparatus was not available for determining electrical conductivity at high (>50°C) temperatures, but it is known that at 50°C the conductivity is considerably more than twice as great as at 20°C, and, from the rate of rise of a curve of conductivity as a function of temperature, it may be assumed that at 80°C it would be many times as great.

The thermal coagulation tests were carried out on 1-liter samples of the raw river water in 2-liter, squat beakers, which were placed on a cold 400-w, 6-in. diameter electric hotplate and provided with a magnetic stirrer.

A thermometer was immersed to its immersion depth (5 cm). The hotplate was then switched on and the magnetic stirrer was operated slowly (the stirrer is not essential, as quite adequate stirring and mixing result naturally from the thermal convection currents). The time was noted.

At the first visible sign of coagulation (formation of a floc about 0.2 mm in diameter) the time and temperature were noted.

The results showed a remarkable sequence in inverse proportion to the original electrical conductivity and another factor which is thought to be closely related to the stability of the colloid. This factor may conveniently be called the relative zeta potential and it is obtained by dividing the sum of time in minutes and temperature in degrees centigrade by the original specific electrical conductivity in micromhos per cubic centimeter at 20°C, as shown in Table 2.

TABLE 2

Calculation of Relative Zeta Potential

Original Electrical Conductivity *μmhos/cu cm*	Coagulation Temperature *°C*	Coagulation Time *min*	Relative Zeta Potential*
150	86	35	0.81
200	81	33½	0.57
260	78	30	0.42
300	77	28	0.35
330	76	28	0.32
430	71	23	0.22
530	68	26	0.18

* Sum of coagulation temperature and time, divided by the original electrical conductivity (at 20°C).

It should be emphasized that no claim is made in favor of this "relative zeta potential" other than the possibility of its usefulness as a guide to the stability of the suspended solids in turbid water supplies.

The coagulation temperature and time are also depressed when electrolytes are added to the water under test, and the rate of depression may indicate coagulating efficiencies of the various mono-, di-, and trivalent electrolytes added. Even sodium metaphosphate in small quantities (1–10 ppm), which could be expected to chelate and form a fairly stable complex with fine suspensions, behaved just like any other electrolyte. The effect of addition of EDTA has not been examined.

Samples of the clear, settled water after cooling showed little chemical change from the original; surprisingly small quantities of the half-bound carbon dioxide were liberated even at 90°C. Turbid river water (350 ppm suspended solids) was heated to various temperatures and cooled to room temperature again. The results are shown in Table 3. These figures are given to show that there was no question of formation of a calcium carbonate precipitate.

Thermal coagulation was applied to samples of turbid river water (190 ppm suspended solids and electrical conductivity of 280) diluted with distilled water to conductivities of 220, 180, 140, 100, and 60 μmhos per cubic centimeter at 20°C, and the results are shown in Table 4.

TABLE 3

Effect of Heating on a River Water with 350 ppm Suspended Solids

Temperature °C	Electrical Conductivity μmhos/cu cm	Alkalinity ppm		pH
		Phenolphthalein	Methyl Orange	
—	155	0	78	8.15
60	159	2	80	8.40
70	161	2	80	8.35
80	160	3	80	8.55
90	167	4	82	8.70
90†	170	5	84	
90‡	178	7	88	8.80

* Not heated.
† Heated for 10 min.
‡ Heated for 30 min.

TABLE 4

Results of Thermal Coagulation of Turbid River Water

Original Electrical Conductivity μmhos/cu cm	Temperature °C	Time min	Evaporation Loss ml	Relative Zeta Potential*
280	77	33	—†	0.39
220	84	39	—†	0.56
180	88	45	—†	0.74
140	93	58	—†	1.08
100	93	96	300	1.89
60	93	160	750	4.22

* Sum of coagulation temperature and time, divided by electrical conductivity (at 20°C).
† Not measured; negligible.

Because of the altitude (these laboratories are about 5,000 ft above sea level, where the barometric pressure is 635 mm Hg and the boiling point of water is 95°C) and because the vessel in which the tests were conducted was neither insulated nor covered, the highest temperature reached was 93°C. It is interesting to speculate on the possibility of conducting similar tests in closed vessels at higher pressures, when it may be found that highly stable colloids will coagulate at temperatures well in excess of 100°C—that is, when the ionic mobilities are great enough to give the suspension medium a high enough electrical conductivity to reduce the zeta potential to zero.

It is noteworthy that the last two dilutions (to electrical conductivities of 100 and 60 μmhos per cubic centimeter at 20°C) did not coagulate until so much water was lost by evaporation that the conductivity after cooling of

the clarified sample reached 140 μmhos per cubic centimeter at 20°C both times.

Before it is visible to the naked eye, the earliest signs of coagulation may be detected by means of Tyndall effect (quantity of scattered light), and this procedure, which has not been tried by the author, may make it possible to determine stability factors when the concentration of suspended solids is less than 50 ppm. The procedure described above produced unreliable results for samples of low turbidity (50 ppm and less).

Summary and Conclusions

The specific electrical conductivity of turbid waters is very important, not only as a measure of the amount of dissolved electrolyte, but also because it gives definite indications of rate of dispersion, relative stability, and base-exchange capacity of the suspended clays and of coagulant doses required for effective coagulation.

When electrical-conductivity measurements (30-sec test) are made at frequent intervals, or by continuous recorder in water from flashy streams, the slightest change in electrolyte concentration can be detected much sooner than by any other means.

In many lakes and large rivers from which water is taken, the ratio between the individual ions present remains fairly constant in spite of considerable variations in total electrolyte content. When this is known to be so, the electrical conductivity will immediately indicate within close limits total dissolved solids, total alkalinity, hardness, and the individual ions. This makes it unnecessary to resort to lengthy analytical procedures.

It is the author's hope that greater interest will be shown by water supply chemists in the significance of specific electrical conductivity; and that the observations and the interpretation reported in this article will both raise criticism and stimulate further work to establish a more useful interpretation of the effects of specific electrical conductivity.

Water Supply Problems at Point Barrow

William L. Boyd and Josephine W. Boyd

A contribution to the Journal by William L. Boyd and Josephine W. Boyd, Bacteriologists, Arctic Research Lab., Point Barrow, Alaska.

A GOOD supply of water is most important to the successful maintenance of either an expedition or a permanent installation in arctic regions. In the past, sources of water on land or from the polar seas have been used either by exploring parties or by people indigenous to these areas. Nansen (*1*) reported that a surface layer of fresh water is sometimes found resting on top of sea water during the thaw when the ice pack is breaking up, and, according to another account (*2*), his party was able to drink water obtained from melted pools on ice floes. Stefansson (*3*) used water derived from ocean ice for five winters while in northern Canada and Alaska. The crew of the "Jeanette" (*4*), however, experienced great difficulty in obtaining water from frozen pools of fresh water on ice floes and finally had to resort to distillation.

On land, the numerous lakes usually serve as sources of water. Members of the International Polar Expedition to Point Barrow (*5*) cut ice in the fall, stored it in a permafrost cellar, and had enough in excess to give to the Eskimos of the vicinity. Mrs. Peary (*6*), while with her husband in Greenland, reported that ice and snow were obtained for water with little difficulty.

Renewed interest in northern areas during the last decade has reemphasized the need for good year-round sources of water for drinking as well as industrial purposes. This report deals with some of the problems encountered at Point Barrow, Alaska, during 1956–57 while the authors were based at the Arctic Research Laboratory.

Nature of Tests

Chemical determinations were carried out on all fresh water samples using special testing kits * and standardized reagents. Ocean chlorinity was assayed by use of a Knudsen buret and silver nitrate standardized against standard sea water † (salinity of 19.375 parts per thousand chloride) and read directly as parts per thousand chloride. All values were converted to parts per million for ease of comparison with the other data.

Potability tests were performed on five 10-ml samples of lake water by techniques outlined in *Standard Methods* (*7*). Bacterial counts were made on dilutions of all samples using tryptone glucose extract agar following incubation at 35°C for 24 hr. Samples from fresh-water sources were collected with a sampling rod at a maximum depth of 8 ft or at the bottom.

Lakes 1–18 were sampled from the floats of a hydroplane, and the other lakes were sampled either from a boat or at a station 4 ft from the shore. Ice

* Nalco; a product of National Aluminate Co., Chicago.

† Supplied by Kahl Scientific Instrument Co., El Cajon, Calif.

samples were collected by chopping to the desired depth with an ice chisel, and ocean water samples were obtained by lowering a bottle to the desired depth, rinsing the bottle with the first sample in each case, and saving the second sample for analysis.

Procurement of Supply

The Native Service Store at Barrow cuts its major supply of ice for winter during September and October when

Fig. 1. Storage Rack for Ice

The two blocks of ice probably represent 1–2 days' supply to be melted for water. The rack is high enough to prevent contamination by sled dogs.

the ice is 10–12 in. thick, and it is hauled either on sleds drawn by tractor or by truck to the village for storage and later sale. Additional supplies are also obtained from some of the lakes during the winter months. Most of the native families in this area either buy ice or harvest enough to last for a few days. Some natives collect "old ice" from the shore ice of the Arctic Ocean in a saucepan or other small container as needed. Figure 1, taken at Point Lay, shows a typical rack for ice storage. The rack is high enough off the ground to keep it safe from contamination by urine and feces of sled dogs.

Where large quantities of water are needed, it is necessary to pump water from under the ice directly into a heated wanigan (Fig. 2) which transports the raw water to a plant for coagulation, chlorination, and other treatment prior to final distribution. Because of the extreme cold and distance from the source, this method is more practical than either pumping water through heated pipelines or preheating the water prior to distribution through pipes.

The water temperature is close to the freezing point during September to June when lakes are covered with ice, and in the summer it rarely rises above 50–55°F. The low yearly temperature influences the speed with which chemicals for treatment react, and laboratory tests as well as recalibration of chemical feeding equipment are necessary, as was recommended by Alter (*8*).

Chlorine Content

Although there are two lakes in the immediate Barrow area which are deep enough not to freeze to the bottom, for logistic reasons it is sometimes necessary to use other sources of water. From the results given in Table 1 it can be seen that ocean ice, especially the "old ice" from floes which are more than 1 yr old, can serve as a limited source of water; the theoretical aspects of the "freshening" of sea ice have been reported by Sverdrup (*9*). Fresh-water ice is practically free of sodium chloride but, like old ocean ice, requires heat to be transformed into the liquid state.

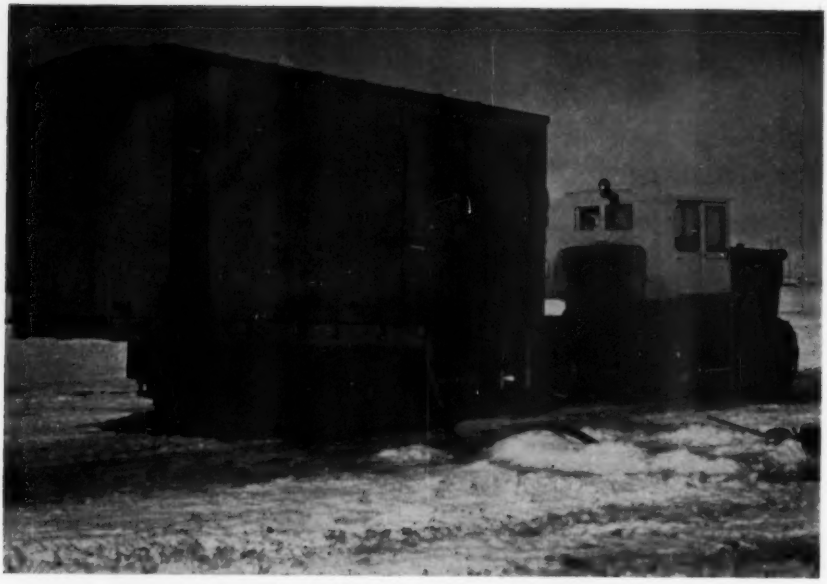


Fig. 2. Wanigan for Water Distribution

Water is being pumped from underneath the ice into two 1,100-gal, heated tanks. The water will be transported to a treatment plant.

TABLE 1

Chloride Concentration in Water From Various Sources, 1957

Date	Source	Chloride Concentration *ppm*	Date	Source	Chloride Concentration *ppm*
Mar. 21	"old ice"	605	Apr. 12	ocean, ½ mi from shore	
Mar. 25	"old ice"	339		ice, surface	8,700
Mar. 30	"old ice"	272		ice, 12 in. deep	5,890
Mar. 31	paleocrystic ice*			ice, 24 in. deep	8,250
	top of ice flow, sample No. 1	96		ice, 36 in. deep	10,000
	top of ice flow, sample No. 2	51		ice, 48 in. deep	6,880
Apr. 22	bottom of ice flow	462		water, below ice	17,730
	snow	6		water, 118 in. deep	17,810
Apr. 5	Imikpuk (Lake 28)			water, 236 in. deep (ocean floor)†	17,810
	ice, surface	13	Apr. 19	ocean, ½ mi. from shore	
	ice, 30 in. deep	5		ice, surface	6,120
	ice, 54 in. deep	5		ice, 12 in. deep	8,000
	water, 108 in. deep (lake bottom)†	416		ice, 24 in. deep	7,630
May 23	Imikpuk			ice, 36 in. deep	3,390
	ice, surface	15		water, below ice	18,020
	ice, 35 in. deep	7		water, 118 in. deep	18,025
	ice, 65 in. deep	10		water, 236 in. deep (ocean floor)†	18,050
	water, 108 in. deep (lake bottom)†	465			

* Stefansson (3) defined paleocrystic ice as ice, one or more summers old, which is characterized by rounded hummocks due to rain and thaw.

† Depths were measured from surface of the ice.

Snow is a relatively poor source because a large volume is needed in proportion to the amount of water produced, and much dust and dirt usually contaminate snow. Because of the micelles of salt which are trapped in the interstitial spaces of its crystal lattice, ocean ice contains far more salt than fresh-water ice, and therefore cannot serve as a water source unless it is treated chemically or distilled.

Ground Water and Lakes

Some unsuccessful attempts have been made to utilize ground water in the Barrow area. Drilling during recent oil explorations (*10*) produced subpermafrost water with a salinity of several thousand parts per million. Therefore, most water is obtained from stored surface sources. In the immediate vicinity of Barrow, only Lakes 19 and 28 can serve as year-

TABLE 2

*Bacterial and Chemical Composition of Lakes of Barrow Area, August 1957**

Day of Month	Lake No.	pH	Concentration—*ppm*					Surface Water Temp. °F	Max Depth *in.*	Bacterial Count per ml
			Chloride (Cl^-)	Total Hardness (as $CaCO_3$)	Calcium Hardness (as $CaCO_3$)	Total Alkalinity ($CaCO_3$)	Iron			
24	23	7.3	19.0	28.5	12.3	16.3	0	50.0	54	3
23	20	7.5	26.7	32.5	20.1	20.1	0	45.0	48	0
23	19	7.1	29.0	16.3	8.7	10.2	0	48.6	78	0
13	10	7.3	29.9	24.5	12.3	10.7	0	47.1	78	1
14	17	7.7	30.6	33.9	19.5	20.3	0.1	41.7	42	4
13	7	7.4	32.5	28.6	16.4	14.5	0	47.1	78	0
13	3	7.5	32.5	32.2	19.5	16.0	0	48.2	78	1
13	4	7.7	32.5	49.2	32.3	31.3	0	46.0	30	2
28	25†	7.5	37.6	47.7	21.6	29.6	1.5	36.3	30	15
13	9	7.2	38.3	24.6	12.9	11.6	0	47.5	90	0
24	21	7.6	44.3	40.8	20.2	17.1	0.5	48.9	30	0
13	2	7.6	46.0	64.6	38.2	38.1	0	47.9	60	0
24	27†	7.5	49.2	36.3	16.3	19.7	0.2	47.9	30	23
13	22	7.4	51.5	84.6	51.7	51.6	0	48.9	18	13
13	13	7.2	51.7	36.5	20.5	11.3	0	47.9	72	0
24	26†	7.6	54.0	52.3	22.3	24.6	0.4	47.9	30	12
14	15	7.8	54.8	56.9	29.1	36.3	0	45.3	72	2
28	24†	7.6	56.5	72.8	38.4	40.0	0.5	36.7	30	8
13	1	7.5	64.0	84.1	37.6	46.7	0	47.5	72	15
13	8	7.6	67.0	67.4	36.5	40.6	0	47.1	60	3
13	12	7.3	69.0	44.5	20.6	12.6	0	44.2	72	0
14	16	7.7	75.0	70.8	32.6	40.8	0	43.2	90	1
13	5	7.7	79.5	80.9	50.6	36.1	0	47.5	60	1
14	14	7.6	89.0	82.5	45.0	48.9	0	43.5	108	0
10	30	8.0	103	114	39.2	79.2	0	33.5	36	1
13	11	7.5	104	76.6	36.6	36.3	0	47.9	96	1
14	18	7.5	107	64.4	28.8	28.4	0.3	42.4	36	1
28	28	7.6	113	62.4	21.4	29.0	0	44.2	108	3
13	6	7.4	152	142	89.2	28.5	0.5	45.7	18	3
23	29	7.6	215	130	48.4	20.0	0	45.3	36	1

* The data presented are the average of two samples.
† Samples from these lakes were not potable.

round water sources (Fig. 3). Lake 28 is used as a source of water and, in addition to Lake 23, is also used as a source of ice by the Eskimo villagers of Barrow.

To the south of Barrow are a number of lakes which are part of the group of oriented lakes described by Black and Barksdale (*11*). These lakes vary in area, depth, and chemical composition. Because of their distance from Barrow, they are used as water sources only by hunters and migrant parties. From the results of the selected chemical analyses given in Table 2, it can be seen that most of the lakes during the ice-free period had a chlorinity which was less than 250 ppm, the upper limit for drinking water suggested by the USPHS Drinking Water Standard (*7*).

The hardness varied from that of natural soft water to hard water according to the classification of Collins (*12*). In all tests the phenolphthalein alkalinity was zero, and the total alkalinity was probably due entirely to bicarbonates. Although manganese was not determined, the concentration of iron alone would sometimes make

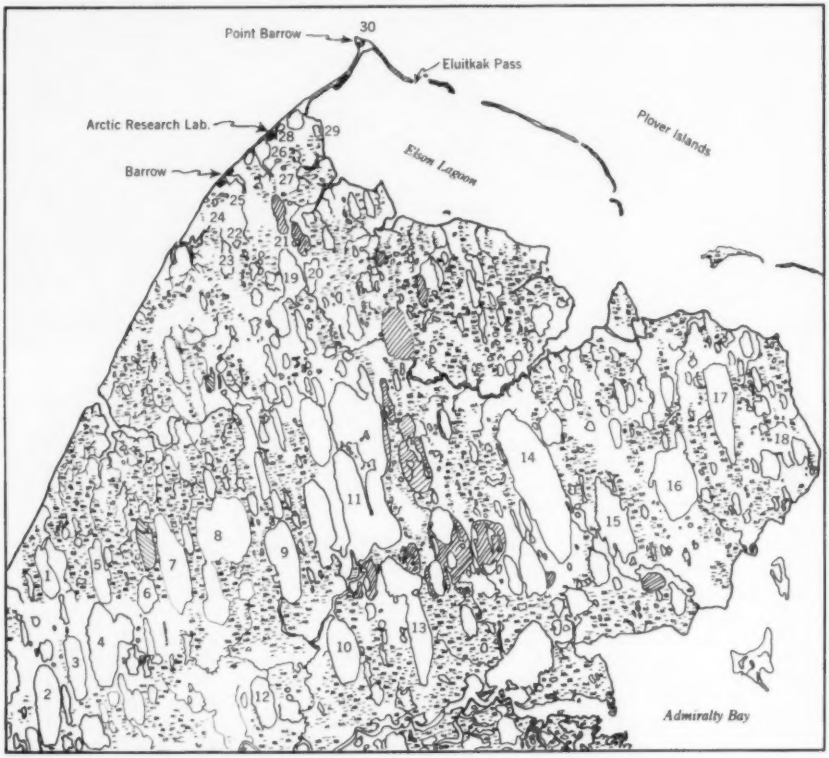


Fig. 3. Barrow Area

All lakes referred to in the text are labeled and shown above.

water from these sources unsuitable for use without chemical treatment. During the summer the pH was on the alkaline side, but it usually drops below 7 during the period of ice cover. Some of the lake water tested could serve as a satisfactory source without treatment.

As most of the lakes were less than 7 ft deep, they could not serve as satisfactory year-round sources of water. Moreover, Boyd (*13*) has reported that a concentration of minerals occurs with an increase in ice thickness, and it would probably be necessary to treat all water for either drinking or industrial purposes sometime during the year. From the limited data presented in Table 3 it would appear that the chemical composition of a given lake is more or less constant from year to year during the ice-free periods, provided that the drainage area is not altered to any great extent. The chemical composition of waters tested was approximately the same during the ice-free period for both years of the study, with the exception of iron, which showed a marked variation. The variation probably was caused by silt, clay, or other matter that was washed into the lake during the runoff.

TABLE 3

*Chemical Composition of Selected Lakes During Ice-Free Period for Two Successive Years**

Lake No.	Date of Sample	pH	Concentration—*ppm*					Surface Water Temp. °F	Maximum Depth *in.*
			Chloride (Cl^-)	Total Hardness ($CaCO_3$)	Calcium Hardness ($CaCO_3$)	Total Alkalinity ($CaCO_3$)	Iron		
28	Aug. '56	7.5	117	64.3	20.8	26.9	0.5	41.2	108
	Aug. '57	7.6	113	62.4	21.4	29.0	0	48.2	108
20	Sep. '56	7.2	25.2	24.2	14.6	12.2	1.5	37.8	48
	Aug. '57	7.5	27.3	32.5	20.1	20.1	0	45.0	48
19	Sep. '56	7.2	28.5	18.1	8.2	6.3	0.5	37.8	78
	Aug. '57	7.1	29.0	16.3	8.7	10.2	0	48.6	78
29	Sep. '56	7.3	234	138	48.3	18.8	0	37.8	36
	Aug. '57	7.6	215	131	48.4	20.0	0	45.3	36
21	Sep. '56	7.2	41.8	32.1	14.4	18.6	1.5	39.2	30
	Aug. '57	7.6	44.1	40.8	20.2	17.1	0.5	48.9	30
22	Sep. '56	7.4	52.0	68.2	44.0	32.8	1.5	35.6	18
	Aug. '57	7.4	51.5	84.6	51.7	51.6	0	48.9	18
23	Sep. '56	7.2	19.1	24.2	12.3	12.5	0	35.2	54
	Aug. '57	7.3	19.0	28.5	12.3	16.3	0	50.0	54
24	Sep. '56	7.3	59.0	64.0	31.6	29.2	3.0	37.4	30
	Aug. '57	7.6	56.6	72.8	38.4	40.0	0.5	36.7	30
30	Sep. '56	8.2	142	125	32.3	87.3	0.5	37.8	36
	Sep. '57	8.0	103	114	39.2	79.2	0	33.4	36

* The data presented are the average of two samples.

All but four of the lakes were free of coliform organisms at the time of sampling. Bacterial counts were generally low, and where coliform bacteria were found ducks and other animals indigenous to the area were probably responsible for their presence. Lakes 24 and 25 are in an area which once was used for sewage disposal and is still used as a refuse dump. From information in Pauls' report (*14*), it seems possible that one of these lakes

was responsible for the epidemic of bacillary dysentery in 1948, which resulted in 105 cases and one death. These data demonstrate the need in polar regions for strict adherence to public health practices in water treatment and sewage disposal. At the present time human waste is placed on the fast ocean ice in 55-gal oil drums and goes out with the ice in the summer.

Conclusions

Various sources of water are present in arctic regions. Problems of water procurement and distribution are encountered because of the extreme cold for most of the year. Treatment of lake water is necessary because the concentration of minerals in the unfrozen water increases with increased ice thickness. Energy, in the form of heat, is necessary either to convert ice or snow into water or to keep stored supplies in a liquid state.

Recent shortages of water throughout the world have turned attention to the use of sea water and brackish water as sources of water for human consumption, agriculture, and industry. Many new methods of water treatment and procurement are now being studied by government and private industry. With the further practical development of atomic reactors for generating cheap power, it may in the future be possible in polar regions to utilize existing supplies of surface waters as well as water from the ocean more economically (*15*).

Acknowledgment

The authors wish to thank Dr. G. Dallas Hanna for collecting many of the "old ice" samples.

These studies were supported in part by a contract between the Office of Naval Research, Department of the Navy, and the Arctic Institute of North America.

References

1. NANSEN, FRIDTJOF. *Farthest North.* Harper & Brothers, New York (1898). p. 104.
2. NANSEN, FRIDTJOF. *The First Crossing of Greenland.* Longmans, Green, London (1896). p. 117.
3. STEFANSSON, VILHJALMUR. *The Friendly Arctic.* The Macmillan Co., New York (1921). p. 32.
4. DELONG, GEORGE W. *The Voyage of the Jeanette.* Houghton Mifflin Co., Boston (1884).
5. RAY, P. H. Report of the International Polar Expedition to Point Barrow, Alaska. US Govt. Printing Office, Washington, D.C. (1885).
6. PEARY, JOSEPHINE W. *My Arctic Journal.* Contemporary Press, New York (1893).
7. Drinking Water Standards. *Public Health Reports.* Reprint No. 2697, USPHS, Washington, D.C. (Mar. 15, 1946).
8. ALTER, AMOS J. *Arctic Sanitary Engineering.* Federal Housing Administration, Washington, D.C. (1950).
9. SVERDRUP, HARALD U. *Arctic Sea Ice.* US Govt. Printing Office, Washington, D.C. (1956).
10. HOPKINS, DAVID M., ET AL. Permafrost and Ground Water in Alaska. Professional Paper 264-F, US Geological Survey, Washington, D.C. (1955).
11. BLACK, ROBERT F. & BARKSDALE, WILLIAM L. Oriented Lakes of Northern Alaska. *Jour. Geol.*, **57**:105 (1949).
12. COLLINS, WILLIAM D. Natural Waters for Industrial Use. *Chem. Eng. News*, **21**:1062 (1943).
13. BOYD, WILLIAM L. Limnology of Selected Arctic Lakes in Relation to Water Supply Problems. *Ecology*, **40**:49 (1959).
14. PAULS, FRANK P. Enteric Diseases in Alaska. *Arctic*, **3**:205 (1953).
15. Needed: An Extra 250 Billion Gallons of Water a Day by 1975. *Chem. Eng. News*, **36**:50 (1958).

Inhibitory Effect of Ointment Tins on Growth of Coliform Organisms in the Membrane Filter Technique

Ralph E. Noble and Marvin Reitman

A contribution to the Journal by Ralph E. Noble, Bacteriologist IV, and Marvin Reitman, Bacteriologist III, South District Filtration Plant, Dept. of Water & Sewers, Chicago, Ill.

THE use of ointment tins in place of small pyrex petri dishes has been proposed for incubating membrane filters inoculated with a water sample. The tins have mechanical advantages in handling and in shipment of the inoculated filters to the laboratory from the sampling point. An objective method based on bacteriological data, rather than on personal opinion, was required for selecting ointment tins or glass petri dishes for incubating inoculated membrane filters. Such a decision was required in a portion of the Chicago South District Filtration Plant program for developing rapid and sensitive procedures for detecting coliform bacteria in water supplies.

The authors (*1*) described a general procedure using a pure culture of *Esch. coli*. (IMViC * reactions of plus, plus, minus, and minus, respectively) for determining the influence of basic fuchsin and sodium sulfite on the productivity of the membrane filter EHC Endo medium. Heavy metal ions are known to be somewhat toxic for bacterial growth. Therefore, a similar study was made to compare the number of coliform organisms developed when membrane filters and pads are incubated in small pyrex petri dishes, with the number that develop when ointment tins are used.

The ointment tins were made of No. 25 electrolytic tin plate without inside lacquer. The outside enamel appeared to be an epoxy resin. The heavy tin plating offered possibilities of toxicity to coliform organisms on the membrane filters by way of the EHC culture medium used as described in *Standard Methods* (*2*) and by Laubusch and others (*3*). In the report of the Metropolitan Water Board (*4*), it is suggested that ointment tins should not be used after rust spots appear, which indicates that the possibility of toxicity is suspected. This precaution was observed routinely in the work at the Chicago South District Filtration Plant.

Purpose of Study

The objective of the research reported here is to find a reliable, sensitive test to determine the potability of waters within 7 hr or less. An intermediate step toward this objective is an attempt to modify the current membrane filter procedure to distinguish low-level potable waters from more

* Indole, methyl red, Voges-Proskauer, and citrate tests, respectively.

potable ones as effectively as it now separates nearly potable water from sewage. Therefore, it is essential to eliminate or minimize known toxic elements likely to reduce the opportunity for a single coliform organism to develop on the membrane filter.

The current study, using a pure culture of *Esch. freundii,* Var. II (IMViC reactions of plus, plus, minus, and plus, respectively), was designed to compare the number of organisms developing on membrane filters incubated on pads in ointment boxes, with the number of organisms developing when the pads were placed in small pyrex petri dishes for incubation.

Experimental Design

In each of 35 replications a different *Esch. freundii* suspension was given four membrane filter counts: A_1 and A_2 for samples incubated in pyrex petri dishes; B_1 and B_2 for samples incubated in 2-oz ointment tins. Four membrane filters were used in each replication. Thus any consistent difference between the number of colonies developing on the filters incubated in pyrex petri dishes, as compared with the number of colonies developing on filters incubated in the 2-oz ointment tins, could be attributed to the type of container, rather than to different bacterial suspensions.

This experimental design reduced the amount of laboratory work required in one day to as little as a single replication. This simplification was possible because the difference in productivity attributable to glass or ointment tin incubation containers was obtained independently from each bacterial suspension. A second advantage of accumulating the individual replications over a period of weeks was that any apparent toxicity was not limited to a single bacterial suspension or to a single set of laboratory test conditions.

Laboratory Procedure

The test organism was a pure culture of *Esch. freundii,* Var. II, which had previously been isolated from untreated Lake Michigan water. The pure culture was grown 24 hr at 35°C in standard lactose broth. It was then streaked on a tryptose glucose extract (TGE) agar slant and incubated 24 hr at 35°C. Then the growth was suspended by adding 5 ml of buffered dilution water to the slant and agitating manually. After brief settling, 2 ml of the suspension was transferred to a sterile 45-ml screw cap vial containing 20 glass beads. The vial was shaken vigorously 25 times to break up possible clumps of cells. An arbitrary

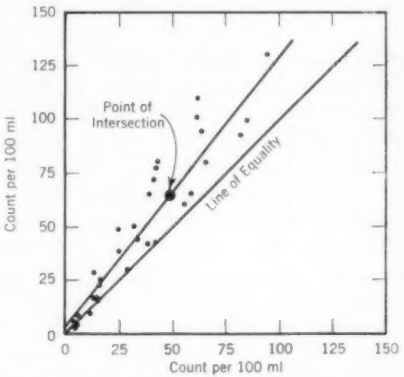


Fig. 1. Comparison of Coliform-Organism Counts From Filters Incubated in Pyrex Dishes and Ointment Tins

As may be seen, all but three of the 35 points, each representing a separate replication, fell above the line of equality. This fact is a clear indication of the inhibitory effect of tin ointment jars on the growth of Esch. freundii.

volume of this suspension was then added to 99.0 ml of sterile, buffered dilution water and shaken 25 times. Aliquots of this suspension were used to prepare subsequent working suspensions of the test organisms. The number of bacteria in these working suspensions was varied during the study to provide a range of 2–150 per 100 ml. A different working suspension was used for each replication.

For each replication, four sterile membrane filters were inoculated with aliquot portions of the same bacterial suspension. Each of two filters was placed on a sterile pad in a pyrex petri dish having an inside diameter of 50×15 mm. Each pad was previously saturated with 2.1 ml of EHC enrichment medium. The dish was then covered and incubated two hours at 35°C. Each of the two remaining filters was placed on a sterile pad, which was also previously saturated with EHC enrichment medium in a 2-oz ointment tin. The latter containers were also covered and incubated as described.

Data and Interpretation

The data consisted of four membrane filter counts from each of the 35 replicate units described in in the experimental design and are presented in Table 1. The pair of counts from filters A_1 and A_2 were averaged to estimate the number of *Esch. freundii* in a given working suspension, capable of growing on membrane filters in pyrex dishes. Similarly ,the corresponding counts from filters B_1 and B_2 were averaged to estimate the number of cells, from the same working suspension, capable of growing on membrane filters in ointment tins. The same EHC culture media were used for growing the test organisms in both sets of containers. For convenience in comparing the two series of averages in Table 1, these data were plotted in the regression diagram in Fig. 1.

The series of data represented by the ointment tins was arbitrarily designated as the independent series, and the other as the dependent series.

TABLE 1

Coliform-Organism Development in Pyrex Petri Dishes and in Ointment Tins, September 1957

Day of Month	No. of Colonies*	
	Pyrex Dishes	Ointment Tins
5	44.0	33.0
5	36.5	25.0
5	17.0	14.5
6	42.5	42.0
6	50.0	50.5
6	51.0	32.0
6	23.0	16.0
6	31.0	28.5
9	100.5	61.0
9	80.5	42.5
9	79.5	65.0
9	65.0	38.0
9	49.0	24.0
10	94.0	63.5
10	98.5	84.0
10	80.5	81.0
10	82.5	63.0
10	77.0	41.5
12	28.5	13.5
12	26.0	16.5
12	16.5	15.0
12	4.0	5.5
12	5.5	3.5
13	17.0	13.5
13	10.0	12.0
13	8.5	5.5
13	4.0	3.5
13	2.5	3.0
17	92.0	82.0
17	66.0	38.5
17	72.5	41.0
17	60.5	55.5
17	42.0	38.0
18	130.5	93.5
18	109.5	62.0

* Average of two replicates.

Thus the average of the pair of counts from filters incubated in ointment tins was considered the independent variable and was measured on the abscissa axis. The average of counts from two filters incubated in pyrex petri dishes was measured on the ordinate axis. In this way, one point was obtained from the data for each of the 35 replications in this study, as shown in Fig. 1.

All points shown in Fig. 1 are expected to fall on the line of equality only if [1] the two types of containers used for incubating the membrane filters exerted no differential influence on the productive power of the culture media used and [2] there was no sampling variation among the colonies on the filters. Under actual test conditions, 32 of the 35 points fell above the line of equality, which indicates that the productivity of the EHC membrane filter medium in pyrex containers was greater than that for the same medium when incubated in ointment tins.

An examination of the data in Table 1 and Fig. 1 shows consistently higher averages for bacterial counts on pairs of filters when incubated in pyrex petri dishes than when incubated in ointment tins. By averaging all data for each series, it was found that the average number of colonies per filter was 51.36 for Series A (pyrex petri dishes) and 37.34 for Series B (ointment tins). The productivity of EHC medium incubated in pyrex containers is, therefore, 137.2 per cent of the productivity of the medium incubated in ointment tins. This is evidence of the inhibitory qualities of the EHC Endo medium when the inoculated filters are incubated in ointment tins—that is, tin or other metallic ions released from the ointment tins may alter the EHC Endo medium in such a way that the medium inhibits the development of some of the less vigorous bacterial cells.

A straight-line regression was fitted to these data, using the method of least squares. This regression line was used to describe the general relationship between the number of colonies from the same bacterial suspension of *Esch. freundii* developing on membrane filters incubated in pyrex dishes as compared to those incubated in ointment tins. (The method of least squares places this line in such a position that it passes through the average of both sets of data (51.36, 37.34) and the sum of squares of the deviations from this line is a minimum.)

The equation is expressed as follows: Estimated count per 100 ml when pyrex dishes are used equals 4.1809, plus 1.2635 times the count per 100 ml obtained when ointment tins are used. It should be noted that this line does not cross the line of equality, as shown in Fig. 1. This is further evidence of the inhibitory action of ointment tins on the productivity of the EHC culture media for growing *Esch. freundii* organisms on membrane filters.

Discussion and Conclusions

These bacteriological tests form an objective basis for decisions regarding the selection of specific items used in bacteriological procedures. Such selections can be made either on an experimental or on a purely subjective basis. When a question of this type arises at the Chicago South District Filtration Plant, a decision based on objective experimental evidence is preferred to one based entirely on personal opinion. The potential toxicity of

heavy metal ions and their salts or complexes is recognized. It is necessary to decide whether the potential toxicity is severe enough to reduce the productivity of the test medium used in ointment tins below its productivity when pyrex petri dishes are used.

This test procedure provided objective experimental evidence that EHC Endo medium incubated in 2-oz ointment tins reduced the number of *Esch. freundii* cells capable of developing, to form visible colonies, below the number developed in pyrex petri dishes. This inhibitory action resulted in underestimation of the number of coliform organisms in the test suspension. The combination of EHC medium with ointment tins was given a productivity rating of 100 per cent. When pyrex dishes were used instead of ointment tins, the average productivity of the medium rose to 137.2 per cent in this study.

Acknowledgment

This study was made possible through the cooperation of John R. Baylis, Oscar Gullans, and James C. Vaughn, all of the Chicago South District Filtration Plant.

Appreciation is expressed to Marjorie L. Sutherland, Illinois Institute of Technology, for statistical counsel and assistance.

References

1. Noble, R. E. & Reitman, Marvin. The Influence of Basic Fuchsin and Sodium Sulfite on the Productivity of the Membrane Filter EHC Endo Medium. *Jour. AWWA*, **51**:614 (May 1959).
2. *Standard Methods for the Examination of Water, Sewage and Industrial Wastes.* APHA, AWWA & FSIWA, New York (10th ed., 1955).
3. Laubusch, E. J.; Geldreich, E. E.; & Jeter, H. L. Membrane Filter Procedure Applied in the Field. *Pub. Health Repts.*, **68**:1118 (1953).
4. 37th Annual Report of the Metropolitan Water Board, London (1955–56).

Effectiveness of Halogens or Halogen Compounds in Detoxifying *Clostridium botulinum* Toxins

A. Richard Brazis, Alton R. Bryant, James E. Leslie, Richard L. Woodward, and Paul W. Kabler

A contribution to the Journal by A. Richard Brazis, Alton R. Bryant, and James E. Leslie, Bacteriologists; Richard L. Woodward, Chief, Water Supply; and Paul W. Kabler, Chief, Microbiology—all of the Water Supply and Pollution Program, Bureau of State Services, USPHS, Robert A. Taft San. Eng. Center, Cincinnati, Ohio.

NORMALLY, *Botulinum* toxins are not present in water and have not posed any health hazard in public water supplies. Five types of *Botulinum* toxin are known. Although they have been extensively studied because of their importance as food poisons, little information is available about their behavior in water and the effectiveness of water treatment in destroying them, should they appear in a water distribution system.

Brygoo (*1*) reported that the five *Botulinum* toxins are destroyed by permanganate, hypochlorite, and iodine in the concentrations ordinarily used for water disinfection. The results indicated that the five toxins (A, B, C, D, and E) were destroyed by the following amounts of chlorine in 15 min: A, 10 mg/l; B, 500 mg/l; C, 50 mg/l; D, 50 mg/l; and E, 500 mg/l. In a more recent paper, D'Arca and D'Arca (*2*) described the effects of free chlorine upon the Type A *Botulinum* toxin. At a minimum lethal dose (MLD) level of 10, 12.5–15 mg/l free chlorine were required when the Type A toxin was held at an ambient temperature for 60 min.

Because of the importance of botulinum toxins as possible agents for intentional contamination of water, the study reported here was undertaken to find suitable methods for protecting against such hazards. Information in the literature indicated that oxidizing agents would destroy the toxin, but the available data were insufficient to provide a suitable basis for design of protective measures.

Nature of Tests

Partially purified and pure forms of *Clostridium botulinum* Types A, B, C, D, and E toxins were used. It was found that the relationship between the survival time of mice injected with toxin and the toxin dose was sufficiently reproducible to serve as a method of assay.

Physical and Chemical Determinations

The methods used in all pH determinations, maintenance of storage temperatures, preparation of neutralizer, stock chlorine mixtures, synthetic test waters, glassware, and buffers have all been described in a previous paper (*3*).

The determination of combined chlorine concentration was made according to the standard orthotolidine test (*4*). Measurements of free available chlo-

rine concentration were made by a modification of the orthotolidine-arsenite method (*4*). It was found that, in the presence of high concentrations of ammonia or other nitrogenous materials, the normal procedure indicated more free available chlorine than was actually present. This difficulty was traced to some color development at 20°C by combined chlorine during the 5-sec period before addition of the arsenite. The difficulty was overcome by a reduction in the temperature of the water to 5°C prior to addition of orthotolidine and arsenite and by more rapid addition of the sodium arsenite. When high concentrations of combined chlorine are present, correction factors similar to those used by Moore (*5*) should be used.

Iodine concentrations were determined by the starch-iodometric method.

Chlorine dioxide concentration was measured according to a procedure, developed by Post and Moore (*6*), in which the sample is allowed to react with malonic acid, which removes free available and combined chlorine when present. Acetate buffer, ferric chloride, and 1-amino, 8-naphthol, 3-6 disulfonic acid are the reagents used for the development of color. Subsequent experience with this procedure indicated that the values obtained may be high when materials that exert a demand are present.

Procedure

Buffered test waters were placed in sterile erlenmeyer flasks and brought to the desired temperature. The halogen solutions and toxins were added to control and test flasks and sampled after specified periods of exposure. At each sampling interval, 5 ml of the test water containing the toxin and the halogen were placed in neutralizer tubes. Male white Swiss mice, weighing 18–20 g, were inoculated in lots of six with 0.6 ml of the neutralized sample.

Times of inoculation and of death of each lot of mice were recorded and used in the determination of toxin concentrations at each sampling interval. All mice were observed over a 4-day period. Mice surviving after 4 days were destroyed. All tests were completed in duplicate.

At the beginning and end of each study pH determinations were made.

TABLE 1

Stability of Partially Purified Clostridium botulinum *Type A Toxin in Water at Various pH Levels and Stored at 25°C*

Exposure Time	Avg Amt of Toxin Remaining—*per cent*					
	pH 6.0	pH 7.0	pH 8.0	pH 9.0	pH 10.0	pH 11.0
3 min	100	100	100	100	100	0.0
1 day	100	100	100	67	13	
3 days	100	100	100	39	0.8	
7 days	60	100	100	28	0.0	
10 days	60	100	93	10		
21 days	37	100	42	0.05		
25 days	37	100	10	0.01		
28 days	37	100	2	0.00		

The effect of the following halogens upon the rate of inactivation of Type A toxin was observed: [1] free available chlorine, [2] monochloramines, mixed monochloramine and dichloramine, and chloramine-T, [3] iodine, and [4] chlorine dioxide. Type B, C, and D toxins were studied only in relation to their resistance to free available chlorine. The resistance of Type E toxin to free available chlorine and chlorine dioxide was evaluated.

Toxin Stability

The stability of partially purified Type A and E toxins was determined in distilled water, buffered (*7*) at pH

6.0, 7.0, 8.0, 9.0, 10.0, and 11.0, and stored either at 25°C or 5°C. Samples of Type A toxin were taken daily throughout a 14-day period and sampled intermittently thereafter. Approximately 20,000–30,000 LD_{50}/ml * were present in each 1-liter aliquot of water examined.

The influence of pH upon the stability of Type A toxin can be seen in Table 1. Except for inconsistencies that occur at pH 6.0, these data show a pattern of increasing instability as pH is increased. The times required for complete destruction of the toxin at pH levels 9.0, 10.0, and 11.0, were 28 days, 7 days, and 3 min respectively. At pH 11.0 the toxin may have been destroyed in less than 3 min, but no earlier samples were taken.

Investigation of the stability of Type E toxin at both 5°C and 25°C at the abovementioned pH levels was limited to 2 days, because of the relatively rapid hydrolysis of the toxin. Table 2 demonstrates the stability of the Type E toxin at the temperatures and pH levels studied. At 25°C, at least 50 per cent destruction at pH levels 8.0 through 11.0, had occurred in less than 1 hr. A lowering of the temperature to 5°C resulted in at least 15 per cent destruction at pH 9.0–11.0 in 4 hr.

TABLE 2

Stability of Clostridium botulinum *Undialyzed Crude Type E Toxin in Water at Various pH Levels and Temperatures*

Exposure Time	Average Amount of Toxin Remaining—*per cent*											
	pH 6.0		pH 7.0		pH 8.0		pH 9.0		pH 10.0		pH 11.0	
	5°C	25°C	5°C	25°C	5°C	25°C	5°C	25°C	5°C	25°C	5°C	25°C
½ min	100	100	100	100	100	100	100	100	100	100	5	0.01
3 min	100	100	100	100	100	100	100	LA*	100	81	0.40	0.00
15 min	100	100	100	100	100	60	100	46	100	LA	0.00	0.00
1 hr	100	100	100	74	100	35	100	21	40	0.20		
2 hr	100	100	100	29	100	17	100	LA	12	LA		
4 hr	100	100	100	10	100	3	85	0.40	7	0.03		
24 hr	35	2.6	8	0.22	2.7	0.1	5.00	0.06	1	0.00		
48 hr	34	LA	4.7	0.20	1.5	0.1	0.15	0.03	0.1	0.00		

* Laboratory accident.

From the results it is apparent that Type A toxin would be little affected, in the normal time of transit, by the hydrogen-ion concentrations normally found in water distribution systems. Type E toxin, on the other hand, is far less stable in water.

Effect of Free Available Chlorine

In the experiments on application of varying chlorine concentrations, it was noted that as long as free available chlorine residuals were present toxin

* [Virulence, or the disease-inciting power of microbes and toxins is measured by the number of organisms or amount of toxin needed to kill members of a particular animal species under standardized conditions and in a definite period of time. Because of variations in the resistance of individuals of a particular species, the endpoint lethal dose (LD) is taken as that dose which kills 50 per cent of the animals—hence the term LD_{50}.—Ed.]

inactivation proceeded rapidly. When a sufficient chlorine demand existed, inactivation was impeded, probably because of the conversion of free available chlorine to combined chlorine, or to the complete reduction of total chlorine. Tables 3–5 show the effects of demand-containing toxins on the initial applied free available chlorine concentrations required to achieve 99.90–99.99 per cent inactivation.

Figure 1 shows 99.99 per cent inactivation of the partially purified Type A toxin in 28, 56, and 103 sec by initial applied free available chlorine concentrations of 0.5, 0.33, and 0.22 mg/l, respectively, at pH 7.0 with storage at 25°C. At pH 7.0 and at 25°C, 99.99 per cent inactivation of Type D toxin required 0.17 and 0.54 mg/l applied free available chlorine for 294 and 30 sec respectively.

Type B, C, and E partially purified toxins contained impurities which exerted appreciable chlorine demands and obscured the effect of varying free available chlorine concentrations. The high chlorine demand of Type E toxin was due mainly to the presence of large amounts of ammonia-nitrogen, as shown in Table 8. When Type E toxins were dialyzed, lower concentrations of free available chlorine were required to obtain 99.90–99.99 per cent inactivation.

At pH 7.0 and at 25°C, applied free available chlorine concentrations of 0.5 and 0.82 mg/l produced 99.99 per cent inactivation in 90 and 27 sec respectively.

TABLE 3

Destruction of Clostridium botulinum *Type A and D Toxins by Free Available Chlorine at Various pH Levels and Temperatures*

Toxin	Temperature °C	pH	Exposure Time—*sec*						Avg Chlorine Concentration *mg/l*			
			15	30	60	120	240	480	Initial		After 120 sec	
			Avg Amount of Toxin Remaining—*per cent*						Free	Total	Free	Total
Type A*	25	7.0	0.80	0.00	0.00	0.00	0.00	0.0	0.50	0.50	0.21	0.21
	25	7.0	0.80	0.07	0.01	0.00	0.00	0.0	0.33	0.33	0.10	0.14
	25	7.0	2.00	0.30	0.06	0.00	0.00	0.0	0.22	0.22	0.00	0.00
	25	7.0	5.00	4.00	3.50	2.90	0.90		0.10	0.10	0.00	0.04
	25	8.0	0.03	<0.01	0.00	0.00	0.00	0.0	0.52	0.52	0.21	0.21
	25	9.0	0.01	0.00	0.00	0.00	0.00	0.0	0.57	0.57	0.29	0.34
	25	10.0	<0.01	0.00	0.00	0.00	0.00	0.0	0.48	0.48	0.19	0.23
	5	7.1	2.00	0.20	0.03	<0.01	0.00	0.0	0.49	0.49	0.24	0.36
	5	8.0	5.00	1.00	0.02	<0.01	0.00	0.0	0.53	0.53	0.21	0.35
	5	9.0	0.60	0.03	0.00	0.00	0.00	0.0	0.53	0.53	0.34	0.40
Type A	25	7.0	0.80	0.05	0.02	0.00	0.00	0.0	0.15	0.15	0.11	0.12
Type D	25	7.0	2.20	0.60	0.20	LA†	0.02	0.0	0.17	0.17	0.11‡	0.12‡
	25	7.0	0.15	<0.01	<0.01	0.00	0.00	0.0	0.54	0.54	0.44	0.45
	5	7.0	2.00	0.70	0.12	<0.01	0.00	0.0	0.59	0.59	0.50	0.53

* Only partially purified.
† Laboratory accident.
‡Concentration found after 480 sec.

An increase in pH appears to increase slightly the toxin-destroying effectiveness of free available chlorine, as is shown in Table 3, but it produces the opposite effect on the bactericidal effectiveness of free chlorine.

Figure 2 shows the influence of temperature on the effectiveness of free available chlorine in destroying Type A and E toxins. A decrease in the temperature from 25°C to 5°C appears to increase 2.5–3.5-fold the time required for 99.95 per cent inactivation. Table 3 shows that for Type D toxin the time required for 99.95 per cent inactivation was increased fourfold by a decrease in temperature from 25°C to 5°C. These studies showed definite differences between the various types of toxins in their resistance to free available chlorine. Based on the studies at pH 7.0 and at 25°C, the resistances of the various toxins appear to be in the following order: E > B > C > D > A.

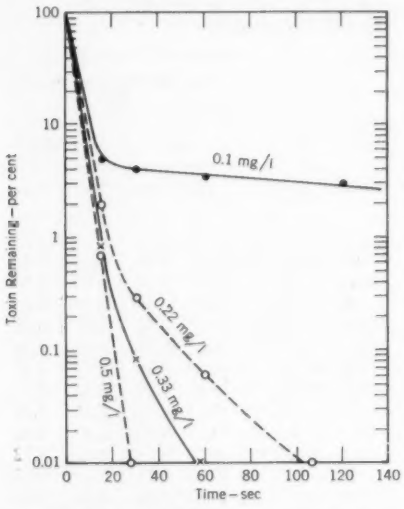


Fig. 1. Effect of Various Concentrations of Applied Free Available Chlorine on the Survival of Partially Purified Type A Toxin at pH 7.0 and at 25°C

Curves A, B, C, *and* D *represent results for applied free available chlorine concentrations of 0.1, 0.22, 0.33, and 0.5 mg/l, respectively.*

Effect of Combined Chlorine

The effect of combined chlorine (chlorine-ammonia) was evaluated under 3 conditions: [1] a mixture of monochloramine and dichloramine; [2] monochloramine; and [3] chloramine-T. The results shown in Table 6 seem to indicate that the mixture of monochloramine and dichloramine was the most effective inorganic chloramine compound investigated for

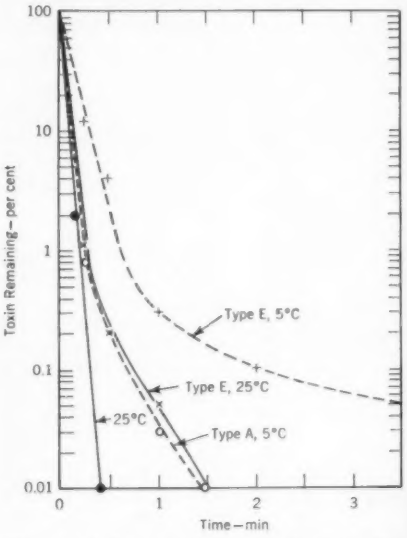


Fig. 2. Influence of Temperature on the Inactivation of *Botulinum* Toxins Exposed to 0.5 mg/l Applied Free Available Chlorine at pH 7.0

The solid and dashed curves represent results at 25° and 5°C, respectively.

inactivating Type A toxin. As maintenance of the proper pH reaction affects the percentage of mono- and dichloramine present under specified conditions of preparation, the ratio between the two forms could not be reliably maintained. As a more reliable compounded form of combined chlorine, 100 per cent monochloramine was used in the remainder of the experiments. Concentrations of 1.0, 5.9, and 11.6 mg/l applied monochloramine produced 25, 99.8, and 99.96 per cent inactivation, respectively, of the partially purified Type A toxin in 4 hr at pH 7.0 and at 25°C.

A toxin was opposite from and much greater than its effect on the effectiveness of free available chlorine. Table 6 shows that an increase from pH 7 to pH 8.0 at 25°C decreased the inactivation from 99.96 to 97.4 per cent after 4 hr when 11.6 mg/l chloramine was used. The much greater effectiveness of free available chlorine than of combined chlorine in destroying Type A toxin is notable.

Effect of Chlorine Dioxide

The interference with free chlorine caused by high ammonia concentrations in some of the Type E toxin suspen-

TABLE 4

Destruction of Partially Purified Type B and C Botulinum *Toxins by Free Available Chlorine at pH 7.0 and at 25°C*

Toxin Type	Exposure Time—*sec*										Avg Chlorine Concentration *mg/l*			
	15	30	60	120	240	480	960	1,800	3,600	4,200	Initial		After 120 sec	
	Avg Amount of Toxin Remaining—*per cent*										Free	Total	Free	Total
B	14.	14.	8.	4.	3.	3.					0.52	0.52	0.00	0.20
B	0.24	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85	1.85	0.46	0.92
C	36.	14.	12.	9.	9.	8.	6.	6.	6.	6.	0.50	0.50	0.00	0.12
C	0.10	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	2.40	0.20	0.59
C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	4.00	0.95	1.00

Although only one concentration of chloramine-T was used, it was considered significant that 99.98 per cent inactivation of the partially purified Type A toxin occurred in 7 min at pH 7.0 and at 25°C, when 11.6 mg/l was applied initially. Thus, in terms of equal concentrations of 11.6 mg/l, the results seem to indicate that chloramine-T is far more effective than monochloramine for inactivation of Type A toxin at pH 7.0 and at 25°C.

The influence of pH on the effectiveness of chloramine in destroying Type

sions suggested the use of chlorine dioxide, which appears to be relatively unaffected by the presence of ammonium salts. During the evaluation of Type E toxin inactivation by free available chlorine, the presence of ammonium sulfate in the undialysed preparations necessitated very high initial free available chlorine doses to inactivate the toxin. Table 7 shows the effect of varying concentrations of chlorine dioxide upon the Type E toxin preparations at pH 7.0 and 25°C. Initial chlorine dioxide concentrations

TABLE 5

Destruction of Botulinum *Type E Toxins of Various Degrees of Purity by Free Available Chlorine at Two pH Levels and Temperatures*

Toxin Description	Temperature °C	pH	Exposure Time—*sec*									Avg Chlorine Concentration *mg/l*			
			15	30	60	120	240	480	960	1,800	3,600	Initial		After 120 sec	
			Average Amount of Toxin Remaining—*per cent*									Free	Total	Free	Total
Undialyzed, crude	25	7.0	86.	86.	63.	63.	63.	25.	16.	16.	2.	7.3	7.3	0.26	5.4
	25	7.0	0.50	0.30	0.15	0.08	0.00	0.00	0.00	0.00		25.	32.	0.10	31.
	25	7.0	0.30	0.17	0.06	0.00	0.00	0.00	0.00	0.00		40.	40.	0.87	37.
	5	7.0	3.	3.	0.60	0.60	0.60	0.40	0.06	0.03		29.	34.	0.04	33.
	25	10.0	0.60	0.50	0.14	0.07	0.05	0.02	0.00	0.00		27.	31.	0.14	29.
Undialyzed, calcium chloride–treated	25	7.0	100	100	100	100	59.	11.	8.	5.		2.9	2.9	0.00	2.4
Undialyzed, purified	25	7.0	10.	6.	6.	6.	2.	1.10	0.30	0.10		5.3	5.3	0.08	5.3
Dialyzed, crude	25	7.0	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00		2.9	3.1	0.00	1.4
Dialyzed, purified	25	7.0	1.10	0.20	0.05	0.00	0.00	0.00	0.00	0.00		0.50	0.50	0.22	0.35
	25	7.0	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.82	0.82	0.64	0.70
	25	7.0	0.26	0.06	0.00	0.00	0.00	0.00	0.00	0.00		1.8	2.1	0.46	1.1
	5	7.0	12.	4.	0.30	0.10	0.05	0.03	0.01	0.00		0.52	0.52	0.28	0.35
	5	7.0	2.60	0.70	0.20	0.08	0.04	0.00	0.00	0.00		0.87	0.87	0.42	0.57

of 0.45–2.0 mg/l produced 99.90–99.99 per cent inactivation of all toxin preparations within 15–30 sec.

In all of the previous investigations of the efficiency of chlorine dioxide and free available chlorine, measurement of the concentrations appeared to be the greatest obstacle to correlation of the results reported by different investigators. This has been especially true where demand substances were suspected of being present and the particular halogen concentration was being determined. By using a new method (*6*) for determining chlorine dioxide, under the conditions of this experiment, the readings obtained were considered to be more reliable. Some questions remain regarding the general use of this method in natural waters containing a variety of interfering substances.

TABLE 6

Destruction of Partially Purified Type A Botulinum *Toxin by Combined Chlorine at pH 7.0 and 8.0 at 25° and 5°C*

Character of Combined Chlorine	Temperature °C	pH	Exposure Time—*min*							Average Combined Cl_2 After Exposure *mg/l*	
			3	7	15	30	60	120	240		
			Avg Amount of Toxin Remaining—*per cent*							Initial	After 4 hr
Mixed mono- and dichloramine	25	7.0	100	100	37.	34.	19.	1.4	0.01	1.0	0.9
	25	7.0	29.	29.	23.	17.	3.	0.1	0.00	1.0	0.9
Monochloramine	25	7.0	48.	48.	33.	12.	12.	6.	0.7	4.1	3.4
	25	7.0	25.	11.	7.	7.	3.	2.	0.2	5.9	5.5
	25	7.0	25.	25.	24.	14.	10.	3.	0.04	11.6	10.
	25	8.0	100	100	100	70.	50.	26.	2.6	11.2	10.
	5	7.0	43.	43.	39.	35.	23.	23.	1.3	11.6	11.3
	5	8.0	100	100	100	80.	73.	73.	27.	11.6	10.3
Monochloramine-T	25	7.0	1.	0.02	0.00	0.00	0.00	0.00	0.00	11.6	11.5

Effect of Iodine

All of these experiments concerned one concentration of iodine. Although the concentration varied slightly between 6.9 and 7.7 mg/l iodine, the difference was not thought to be significant in terms of the results sought. The iodine concentration was prepared by dissolving one Globaline tablet per quart of disinfected tap water. The stability of the tablets (time in tablet form since manufacture) affected the final concentration in the test waters.

Iodine effectiveness was determined in tap waters containing high and low concentrations of carbonate hardness. The data appeared to indicate that in waters of low carbonate hardness (48 mg/l), 6.9 mg/l iodine produced more than 99.99 per cent inactivation of Type A partially purified toxin in 60 sec at pH 6.25 and 25°C. In waters of high carbonate hardness (385–430 mg/l), 7.2–7.7 mg/l iodine effected greater than 99.99 per cent inactivation in less than 15 sec at pH 8.1 and at 25°C. These results suggest that hypoiodous acid at pH 8.10 is more efficient in inactivating Type A toxin than is the free iodine present at pH 6.25. This effectiveness of hypoiodous acid over free iodine has been confirmed in viricidal studies by Berg (*8*).

Discussion

From the experimental work it is clear that either free available chlorine or chlorine dioxide can provide effective protection against *Clostridium botulinum* toxins. Such protection will be required only as a result of intentional contamination, however.

The most effective method of contamination would be to introduce the toxin directly into a distribution system. The vulnerability of distribution systems to intentional contamination need not be labored. It would be virtually impossible to prevent a determined saboteur from gaining access to a system. Therefore, protective measures must be taken near the point of use at attractive targets.

A little arithmetic serves to determine the order of magnitude of the quantities required for serious contamination of a water supply. In a few human cases it has been possible to assay the toxin concentration in the offending food and to estimate the quantity of food consumed. In one such case, well documented both as to toxin concentration and food consumption, Meyer and Eddie (*9*) found that 3,500 mouse lethal doses caused a rapid, fatal intoxication. From other investigations they concluded that a few hundred mouse lethal doses could poison human beings.

Pure crystalline Type A *Botulinum* toxin contains about 30 billion mouse lethal doses per gram (*10*), but the toxin is relatively unstable in crystalline form. The less highly purified materials used in this study contained about 1,000,000–250,000,000 mouse doses per milliliter. A toxin concentration of about 10 mouse doses per

TABLE 7

Destruction of Botulinum *Type E Toxins by Chlorine Dioxide at pH 7.0 and 9.0 at 25° and 5°C*

Toxin Description	Temperature °C	pH	Exposure Time—*sec*								Avg Chlorine Dioxide Concentration *mg/l*	
			15	30	60	120	240	480	960	1,800		
			Avg Amount of Toxin Remaining—*per cent*								Initial	After 120 sec
Undialyzed, crude	25	7.0	0.30	0.30	0.30	0.30	0.30	0.30	0.09	0.09	0.90	0.12
	25	7.0	0.06	0.04	0.04	0.02	0.01	0.00	0.00	0.00	1.9	0.18
	5	7.0	0.07	0.06	0.06	0.05	0.00	0.00	0.00	0.00	1.8	0.17
Undialyzed, calcium chloride–treated	25	7.0	<0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.2	0.09
	5	7.0	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.00
Undialyzed, purified	25	7.0	<0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.1	0.82
	5	7.0	<0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.0	0.80
Dialyzed, crude	25	7.0	0.40	0.40	0.24	0.00	0.00	0.00	0.00	0.00	0.49	0.11
	25	7.0	<0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.0	0.15
	5	7.0	<2.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.08
Dialyzed, purified	25	7.0	<0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.27
	5	7.0	0.05	<0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.25
Undialyzed, purified	5	9.0	0.02	<0.01	0.00	0.00	0.00	0.00	0.00	0.00	1.0	0.76

milliliter would be likely to give a human fatal dose in a drink of water.

Using a suspension of 100,000,000 mouse doses per milliliter one would need almost a pint to contaminate 1 mil gal of water to the lethal level. Less highly purified suspensions or larger volumes of water would require correspondingly more. Thus the scare idea, often propounded by the popular press, of a madman poisoning the water supply of a large city with the contents of a small vial is seen to be exaggerated. Nevertheless, the possibility of poisoning sizable numbers of people with relatively small amounts of material must be considered.

TABLE 8

Influence of Ammonia-Nitrogen on the Rate of Inactivation of Botulinum *Type E Toxins, With an Initial Concentration of 3 mg/l Chlorine at pH 7.0 and 25°C*

Toxin Description*	NH_3-N (mg/l) in Water Containing Toxin Minus Free Available Chlorine	NH_3-N (mg/l) in Water Containing Toxin Plus Free Available Chlorine		Time Needed to Produce 95% Inactivation *min*
	0 sec	20 sec	15 min	
Undialyzed crude	15.0	13.	7.	>30
Undialyzed calcium chloride treated	8.5	8.5	4.	>30
Undialyzed pure	0.20	0.15	0.10	8
Dialyzed crude	0.02	0.00	0.00	<1
Dialyzed pure	<0.01	0.00	0.00	<1

* Stage of purification of Type E toxin.

Chlorine Residual in Distribution Systems

Maintenance of free chlorine residuals in a distribution system would seriously interfere with attempts at sabotage. The chlorine residual could be neutralized with various reducing agents but some corresponding increase in the quantities of toxin would be necessary.

The sudden disappearance of a free chlorine residual might serve as a warning of contamination. This has been suggested by Berger and Stevenson (*11*) and others as a warning or detection device. The feasibility of such a device would depend upon the variability of residual chlorine levels in the distribution system. If they are frequently zero or if variations in residual levels are wide and frequent enough to give rise to false alarms, this procedure would not be feasible as a warning of contamination.

Relatively little is known about the diurnal or short-time variations of chlorine residuals in distribution systems. Plowman and Rademacher (*12*) found relatively small and slow fluctuations in combined chlorine residuals in the Gary-Hobart system. In another large system frequent and wide fluctuations have been attributed to the layout, which included a pressure-compensating reservoir.

It is clear that the use of chlorine residual measurements to detect contamination would require study of individual situations. For points of critical significance, chlorine residual recorders, booster chlorinators, and chlorine contact tanks to assure suitable holding times would be needed if contamination were to be counteracted.

It should be emphasized that combined chlorine residuals are not so effective as free residuals in destroying *Botulinum* toxins. This comparison is also true of bacteria, which might be used as sabotage weapons.

Conclusions

Inactivation of *Clostridium botulinum* toxins by free available chlorine has been shown to occur as long as a residual of free available chlorine remains in the water. The rate of destruction of the toxins by free available chlorine at 25°C is not markedly affected by pH in the range 7.0–10.0. Lowering the temperature from 25° to 5°C approximately triples the time required for 99.90–99.99 per cent destruction of the toxins. Free available chlorine concentrations of less than 0.5 mg/l were not able to satisfy the chlorine demand of the partially purified Types B, C, and E toxins. In the pH range of 7.0–10.0, 0.5 mg/l free available chlorine caused 99.90–99.99 per cent inactivation of the partially purified Type A toxin in 15–30 sec at 25°C.

Chloramines are relatively ineffective in destroying *Botulinum* toxins. Inactivation of the partially purified Type A toxin by solutions of dichloramine and monochloramine was affected by changes in pH, temperature, and exposure time.

Iodine appeared to be more effective at pH 8.1 than at pH 6.25 in terms of the time required to produce a 99.90–99.99 per cent inactivation of the partially purified Type A toxin.

Chlorine dioxide appears to be superior to free available chlorine in destroying *Botulinum* toxin. Uncertainty as to the bactericidal effectiveness of chlorine dioxide and the analytical method for its measurement in natural waters make it unwise to recommend its use in place of chlorine as a general protective measure against biological agents.

The work reported in this article was performed under contract with the Department of the Navy, Bureau of Yards and Docks. Toxins were supplied by E. J. Schantz and James Duff of Fort Detrick, Frederick, Md.

References

1. Brygoo, E. R. Action of Disinfectants on Botulinus Toxins Diluted in Water. *Ann. Inst. Pasteur,* **84**:1,040 (1953).
2. D'Arca, S. & D'Arca, S. A. Further Studies on the Detoxifying Power of Free Active Chlorine With Respect to Type A *Botulinum* Toxin. *Nuovi Ann. Igiene e Microbiol.,* **4**:355 (1955).
3. Brazis, A. R., et al. The Inactivation of Spores of *Bacillus globigii* and *Bacillus anthracis* by Free Available Chlorine. *Appl. Microbiol.,* **6**:339 (1958).
4. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.* APHA, AWWA, & FSIWA, New York (10th ed., 1955).
5. Moore, E. W. Fundamentals of Chlorination of Sewage and Waste. *Wtr. & Sew. Wks.,* **98**:130 (1951).
6. Post, M. & Moore, W. Allan. Determination of Chlorine Dioxide in Treated Surface Waters. *Anal. Chem.* (in press).
7. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.* APHA, AWWA, & FSIWA, New York (9th ed., 1946).
8. Berg, Gerald. Private communication (1959).
9. Meyer, K. F. & Eddie, B. Perspectives Concerning Botulism. *Hyg-Infektionskrankh.,* **133**:255 (1951).
10. Lamanna, C.; McElroy, O. E.; & Erlund, H. W. The Purification and Crystallization of *Clostridium botulinum* Type A Toxin. *Science,* **103**:613 (1946).
11. Berger, B. B. & Stevenson, A. H. Feasibility of Biological Warfare Against Public Water Supplies. *Jour. AWWA,* **47**:101 (1955).
12. Plowman, H. L. Jr. & Rademacher, J. M. Persistence of Combined Available Chlorine Residual in Gary-Hobart Distribution System. *Jour. AWWA,* **50**:1,250 (1958).

AWWA Meter Manual

Chapter 4—Meter Selection for Accurate Measurement of Various Customer Demands

A manual on water meter selection, installation, testing, and maintenance has been prepared by AWWA Committee 8610—Meters. The document is being published in installments (June 1959 issue, p. 790), and will afterwards be made available as a separate volume.

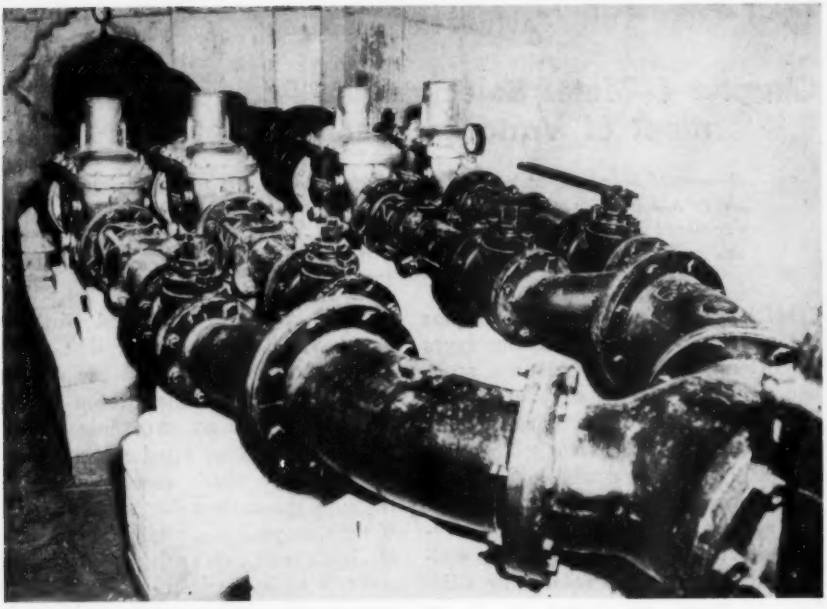
THE selection of water meters for installations serving various types of customers usually presents a problem only when larger commercial and industrial accounts are under consideration; however, apartment buildings, schools, other large establishments, and the combination of private fire service and general use through a single service (when permitted) also require considered judgment if a reasonably satisfactory meter installation is to be obtained.

Small Flows

There is only one type of water meters manufactured in the United States in $\frac{5}{8}$-in., $\frac{3}{4}$-in. and 1-in. sizes. These meters are of positive-displacement design and are commonly known as nutating-disc (disc) and oscillating-piston (piston) meters. Experience has shown that these meters record the range of flows encountered in premises which use water at small flow rates more accurately and for longer periods than any other type and best register small leaks which develop in plumbing systems. This is not unusual, as these meters are the survivors of many types developed for measuring water used in dwellings. The safe maximum operating capacities of positive-displacement meters as shown in AWWA C700 are as follows: $\frac{5}{8}$-in., 20 gpm; $\frac{3}{4}$-in., 30 gpm; and 1-in., 50 gpm. It should be noted that these quantities are those which the meters are to deliver with rated piston speeds and friction loss not exceeding 15 psi. Furthermore, these rated capacities are rates of flow which should be passed through the meters for short periods of time, or peak loads which occur only at infrequent intervals, if excessive wear is to be avoided. For domestic service installations, this problem is not frequently encountered and inadequate water service is seldom traceable to the size of meter. Because the type of water service experienced by a customer depends on numerous factors, of which the meter is only one, Chapter 5 should be consulted for determining service and meter sizes for specific conditions and will also be found of value in determinations of probable causes of deficiencies in existing installations. Water usage in ordinary homes seldom is in excess of 35–40 per cent of rated meter capacity. This fact accounts in large measure for the many years of dependable service obtained from positive-displacement meters.

Medium Flows

For the intermediate class of accounts between small and large, arbitrarily designated as those which can



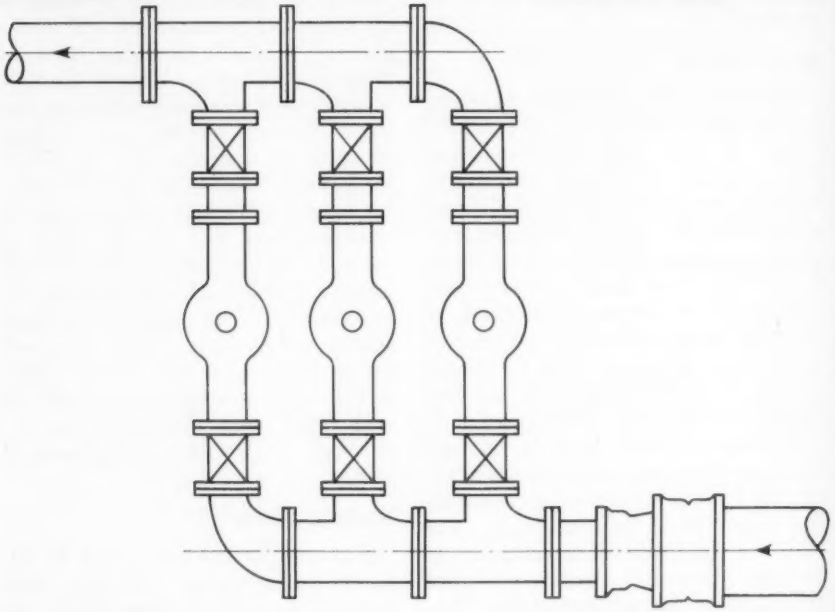
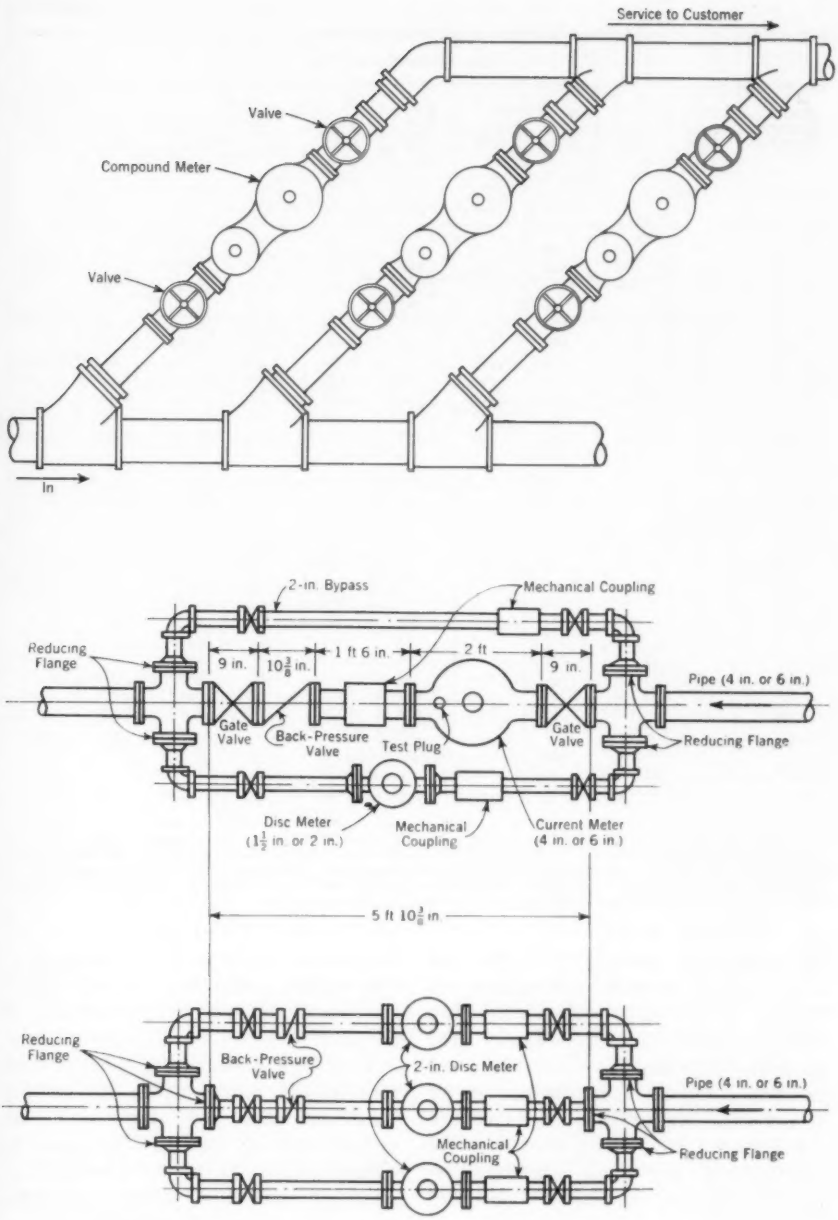


Fig. 4.1. Examples of Various



Flexible Battery Installations

TABLE 4.1

Percentage of Safe Maximum Operating Capacity*	Meter Size and Type									
	¾-in. Disc	1-in. Disc	1½-in. Disc	2-in. Disc, Compound, & Current	3-in. Disc	3-in. Compound	3-in. Current	4-in. Disc	4-in. Compound
30-day Continuous Registration—*1,000-gal units*									
10	86	130	216	432	691	1,296	1,382	1,728	2,160	2,160
20	173	259	432	864	1,382	2,592	2,765	3,456	4,320	4,320
30	259	389	648	1,296	2,074	3,888	4,147	5,184	6,480	6,480
33⅓					2,304		4,608	5,760		7,200
40	346	518	864	1,728	2,765	5,184	5,530	6,192	8,640	8,640
50	432	648	1,080	2,160	3,456	6,480	6,912	8,640	10,080	10,080
60	518	778	1,296	2,592	4,147	7,776	8,294	10,368	12,960	12,960
70	605	907	1,512	3,024	4,838	9,072	9,677	12,096	15,120	15,120
80	691	1,037	1,728	3,456	5,530	10,368	11,059	13,824	17,280	17,280
90	778	1,166	1,944	3,888	6,221	11,664	12,442	15,552	19,440	19,440
100	864	1,296	2,160	4,320	6,912	12,960	13,824	17,280	21,600	21,600
30-day Continuous Registration—*1,000-cu ft units*										
10	12	17	29	58	92	173	184	230	288	288
20	23	35	58	115	184	346	369	461	576	576
30	35	52	86	173	277	518	553	691	864	864
33⅓					307		614	768		960
40	46	69	115	230	369	691	737	922	1,152	1,152
50	58	86	144	288	461	864	922	1,152	1,440	1,440
60	69	104	173	346	553	1,037	1,106	1,382	1,728	1,728
70	81	121	202	403	645	1,210	1,290	1,613	2,016	2,016
80	92	138	230	461	737	1,382	1,475	1,843	2,304	2,304
90	104	156	259	518	829	1,555	1,659	2,074	2,592	2,592
100	115	173	288	576	922	1,728	1,843	2,304	2,880	2,880
Safe Maximum Operating Capacity*—*gpm*										
	20	30	50	100	160	300	320	400	500	500

* "Safe maximum operating capacities" (in gallons per minute) apply only for short periods of operation or peak loads occurring at long intervals. To avoid possible excessive wear, disc meters should not be operated continuously at more than 20 per cent of the safe maximum operating capacity; compound or current meters should not be operated continuously at more than 33⅓ per cent of the safe maximum operating capacity. The 30-day continuous registration equivalent to these percentages is underscored for each meter.

be adequately served by 1½-in. and 2-in. meters, there are three types of meters available, all of which have been extensively used. These are: positive-displacement, current, and compound types. The current meter is not sensitive to small rates of use (or leakage) and usually should not be used where very small flows are frequent. Current meters are designed for installations in which the consumption ranges somewhere around ⅓–½ of the listed safe operating capacity of the unit.

The limited sensitivity of the current meter narrows the choice for most accounts requiring maximum meter capacity of 50–160 gpm to either a 1½- or 2-in. positive-displacement or compound meter, and both

Monthly Continuous Meter Registration

Percentage of Safe Maximum Operating Capacity*	Meter Size and Type										
	4-in. Current	6-in. Disc	6-in. Compound	6-in. Current	8-in. Compound	8-in. Current	10-in. Compound	10-in. Current	12-in. Compound	12-in. Current	16-in. Current
	30-day Continuous Registration—*1,000-gal units*										
10	3,024	4,320	4,320	6,912	6,912	10,800	9,936	16,416	13,392	25,056	49,248
20	6,048	8,640	8,640	13,824	13,824	21,600	19,872	32,832	26,784	50,112	98,496
30	9,072	12,960	12,960	20,736	20,736	32,400	29,808	49,248	40,176	75,168	147,744
33⅓	10,080		14,400	23,040	23,040	36,000	33,121	54,720	44,640	83,520	164,160
40	12,096	17,280	17,280	27,648	27,648	43,200	39,744	65,664	53,568	100,224	196,992
50	15,120	21,600	21,600	34,560	34,560	54,000	49,680	82,080	66,960	125,280	246,240
60	18,144	25,920	25,920	41,472	41,472	64,800	59,616	98,496	80,352	105,336	295,488
70	21,168	30,240	30,240	48,384	48,384	75,600	69,552	114,912	93,744	175,392	344,736
80	24,192	34,560	34,560	55,296	55,296	86,400	79,488	131,328	107,136	200,448	393,984
90	27,216	38,880	38,880	62,208	62,208	97,200	89,424	147,744	120,528	225,504	443,232
100	30,240	43,200	43,200	69,120	69,120	108,000	99,360	164,160	133,920	250,560	492,480
	30-day Continuous Registration—*1,000-cu ft units*										
10	403	576	576	922	922	1,440	1,325	2,188	1,786	3,341	6,566
20	806	1,152	1,152	1,843	1,843	2,880	2,650	4,376	3,571	6,682	13,133
30	1,210	1,728	1,728	2,765	2,765	4,320	3,975	6,564	5,357	10,023	19,699
33⅓	1,344		1,920	3,072	3,072	4,800	4,417	7,291	5,952	11,137	21,888
40	1,613	2,304	2,304	3,686	3,686	5,760	5,300	8,752	7,142	13,364	26,266
50	2,016	2,880	2,880	4,608	4,608	7,200	6,625	10,940	8,928	16,705	32,832
60	2,419	3,456	3,456	5,530	5,530	8,640	7,950	13,128	10,714	20,046	39,398
70	2,822	4,032	4,032	6,451	6,451	10,080	9,275	15,316	12,499	23,387	45,965
80	3,226	4,608	4,608	7,373	7,373	11,520	10,600	17,504	14,285	26,728	52,531
90	3,629	5,184	5,184	8,294	8,294	12,960	11,925	19,692	16,070	30,069	59,098
100	4,032	5,760	5,760	9,216	9,216	14,400	13,250	21,880	17,856	33,410	65,664
	Safe Maximum Operating Capacity*—*gpm*										
	700	1,000	1,000	1,600	1,600	2,500	2,300	3,800	3,100	5,800	11,500

types have their advocates. Those who favor the compound meter feel that water at very low rates measured by the small disc meter section of the compound meter would not be measured were a single 1½- or 2-in. disc meter installed. Obviously, a ⅝-in. disc meter is sensitive to lower rates of flow than either 1½- or 2-in. disc meters, and theoretically, at least, the use of 1½-in. and 2-in. compound meters is justified.

Those who favor 1½- and 2-in. disc meters use them with the knowledge that potential underregistration or nonregistration of very small rates of flow is possible, but believe that the actual loss in registration is negligible due to compensating loss of accuracy in the changeover range of flows of compound meters. Obviously, the accuracy of registration under actual service conditions is a variable and depends on the quantities of water used at various rates of flow by a particular customer. The lack of comparative laboratory or shop tests which might provide conclusive answers under all

service conditions results in the variable installation practices noted, and reliance is placed mainly on individual preference.

Large Flows

Large accounts—that is, those with demands in excess of 160 gpm which thereby require 3-in. or larger meter capacity—may be broadly classified in three categories:

1. Those whose use covers a wide range of flows ranging from very small to those approaching meter capacity

2. Those whose normal use is usually at low or medium rates of flow but which require large meter capacity only infrequently, such as for private fire service facilities

3. Those which use water at sustained high rates of flow only.

The same problem encountered in the selection of 1½- and 2-in. meters is encountered in larger meter installations, but it is more acute because the third type, the current meter, must also be considered. Furthermore, the larger meters are heavy and often repaired and tested in place. When a

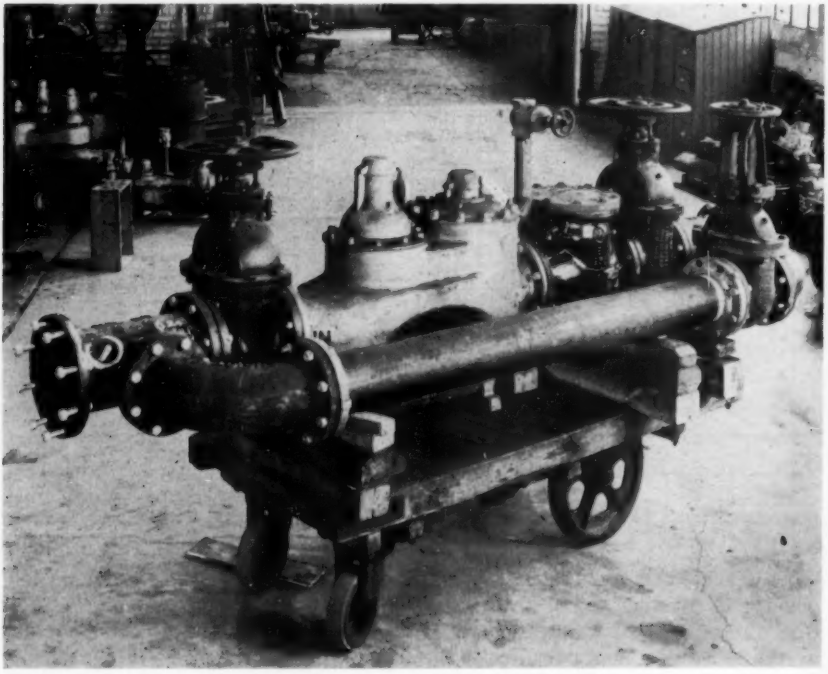


Fig. 4.2. Setting for 8-in. Compound Meter

The setting will be installed with the bypass in one unit, which simplifies installation.

single, large meter is installed, bypass piping should be provided in order that meter maintenance can be accomplished without service shutdown.

The principle of installing meters in batteries of two or more has become accepted. These battery installations may consist of two or more compound, current, or disc meters or combinations of the three types. The value of battery and single-unit installations can best be judged only by the preference of the individual responsible for the installation. Many prefer the single-unit installation while others prefer the battery installation. The only suitable way to select a proper meter installation is to weigh all of the facts that are available.

Figure 4.1 shows several methods of piping used to provide flexibility for future changes of meter sizes and combination of meters at minimum expense. The use of flexible coupling to provide for easy removal of the meters from the line is recommended. Figures 4.2 and 4.3 show good piping arrangements for compound meter settings.

Undoubtedly, the tendency to oversize meters in the past resulted in large measure from the natural tendency to use a meter known to be large enough to satisfy the customer's maximum demands and not gamble on having to go to additional expense if a smaller meter was later found inadequate. Once a single large meter is installed and use does not occur to justify the large meter, probable loss due to underregistration on low flows is not generally considered sufficient to cover the cost of reducing meter size unless the original piping arrangement allows for such an eventuality.

Valuable information concerning rates of use by specific customers can be obtained by the use of rate-of-flow recorders. These instruments provide a graphic record of actual use, which is particularly helpful in determining proper meter size or the best arrangement to record consumption. Unfortunately, such data cannot be determined for new accounts until after meter installation, either temporary or permanent, is made. If, however, initial provision is made for changes in meter capacity or arrangement, a proper adjustment is much more likely to be made.

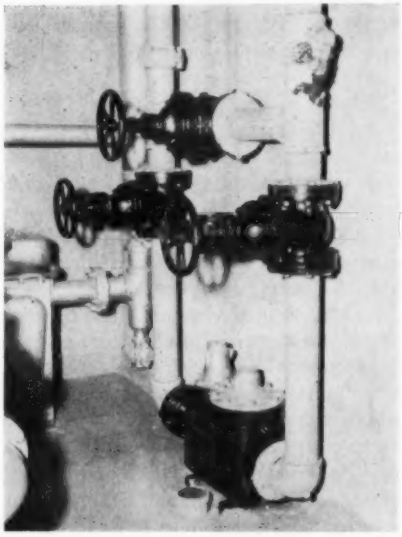


Fig. 4.3. Large Compound Meter Setting

Table 4.1 has been prepared to show the quantities that water meters are capable of recording at various percentages of rated capacities, as established by AWWA standards, if water is used at continuous, uniform rates for

30 days. The table shows the very large quantities that meters will deliver within design limits. Listed safe maximum operating capacities (in gallons per minute) apply only for short periods of operation or a peak load that occurs only at widely separated intervals. Such rates of flow would be destructive under continuous operation. To avoid excessive wear, disc meters should not be operated continuously at more than 20 per cent of listed safe maximum operating capacity, nor should current or compound meters be operated at more than 33⅓ per cent of their maximum operating capacity. If the table is used with discretion and adjustments are made to compensate for intermittent use, overmetering should be markedly reduced.

Chapter 5—Effects of Friction and Pressure Losses on Service Adequacy

ADEQUACY of service to a customer depends on numerous factors. The relationship between these factors is unfortunately not always considered before service and meter installations are made, with the result that when deficiency of service is encountered, measures of expediency are taken which do not correct the basic cause or causes of the deficiency. A list of the important factors is given below:

1. Pressure and quantity of water available in the main at the point of service connection
2. Differences in elevation between the main in the street and water fixtures on the customer's premises
3. Friction loss in the service line from the main in the street to the curb or property line
4. Friction loss in the service line from curb or property line to the building
5. Meter friction loss
6. Friction loss in house piping and fixtures
7. Rates at which water is used by the customer.

All of these factors must be considered in determinations of the size of service and meter required to provide adequate service. As the water utility does not generally have responsibility or control over the pipe sizes within a customer's building, the total friction loss of the facilities to be installed by the utility should be such as to provide for reasonable losses within the building. The difference in elevation to the highest water outlet and residual pressure at that point during periods of maximum use by the customer should be taken into account.

Sample Problem

For purposes of illustration, let it be assumed that service is to be provided for a residential customer and that a pressure of 20 psi at the point of entry to the home (after the meter) is considered necessary to provide a maximum flow of 15 gpm. If the backup facilities are adequate and such that normal minimum pressure in the main at the service connection is 50 psi, combined service and meter losses cannot exceed 30 psi if these conditions are to be met during periods of maximum use by the customer. A number of combinations of service and meter sizes would meet this requirement. Data from capacity and friction loss curves of meters are noted in Table 5.1.

TABLE 5.1

*Friction Losses of ⅝–1-in. Meters at 15 gpm**

Meter Size *in.*	Rated Capacity *gpm*	Friction Loss *psi*
⅝	20	8.4
¾	30	3.8
1	50	1.4

* Data are based on current AWWA standards; higher losses may be experienced with meters of older or other design.

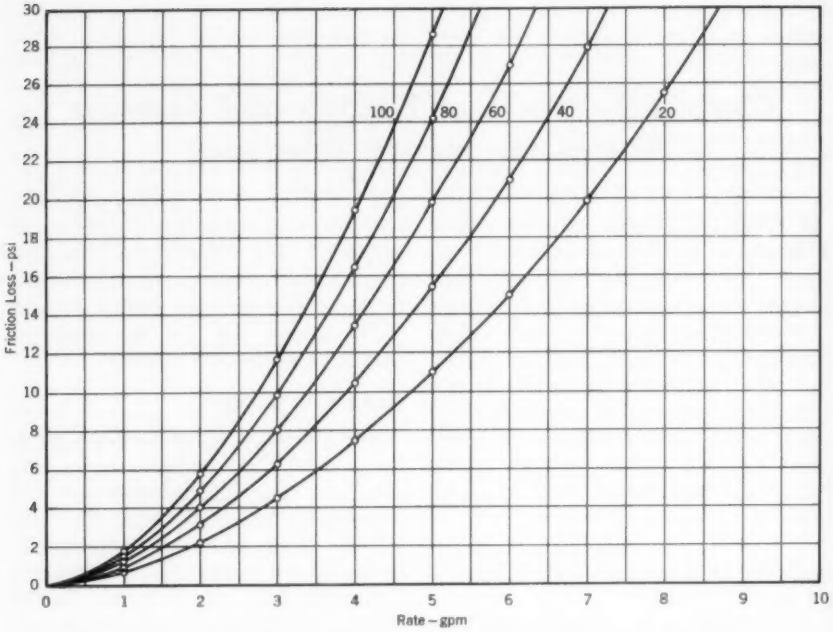


Fig. 5.1. Computed Friction Losses, ½-in. Copper Service With ⅝-in. Meter

Numbers identifying curves indicate length of service, in feet.

TABLE 5.2

Computed Friction Losses for ½-in. Copper Services With ⅝-in. Meter

Rate *gpm*	Service Length—*ft*				
	20	40	60	80	100
	Computed Friction Loss—*psi*				
1	0.63	0.91	1.19	1.47	1.75
2	2.20	3.10	4.00	4.90	5.80
3	4.44	6.24	8.04	9.84	11.64
4	7.49	10.49	13.49	16.49	19.49
5	11.05	15.45	19.85	24.25	28.65
6	14.97	20.97	26.97	32.97	38.97
7	19.93	27.93	35.93	43.93	51.93
8	25.54	35.74	45.94	56.14	66.34
9	31.64	44.24	56.84	69.44	82.04
10	39.11	54.71	70.31	85.91	101.51

If a $\frac{5}{8}$-in. disc meter were decided upon, there would still be available approximately 21.5 psi to cover friction loss in the service piping from the main in the street to the house. Obviously, this loss depends on the length of the service line, and, for this purpose, let it be assumed that the distance is 80 ft.

From data on friction losses in Type K copper tubing, it can be seen that the approximate losses at 15 gpm are 29 psi per 100 ft of $\frac{3}{4}$-in. Type K copper tubing, and 7.0 psi per 100 ft of 1-in. Type K copper tubing.

With $\frac{3}{4}$-in. service pipe 80 ft long, there would be approximately a 23-psi loss in the pipe alone, not including fittings, and the design conditions would not be met with a $\frac{3}{4}$-in. copper service and $\frac{5}{8}$-in. disc meter. Actually, the allocation of 30 psi for service and meter friction losses and only 20 psi for house piping losses and elevation differences is not to be considered to represent proper design considerations and has been used only for illustrative purposes. The example does, however, show why it is not possible to adopt a standard size service or meter for a given class of customer, principally because of variations in pressures available in different areas of a distribution system, which, in turn, depend upon terrain and main capacity.

TABLE 5.3

*Computed Friction Losses for $\frac{1}{2}$-in. Service Components**

Rate *gpm*	Fittings and Meter					Pipe Length—*ft*				
	$\frac{1}{2}$-in. Corporation†	$\frac{1}{2}$-in. Curb Stop‡	$\frac{1}{2}$-in. Globe Valve§	$\frac{5}{8}$-in. Disc Meter‖	Total, Fittings & Meter	20	40	60	80	100
	Computed Friction Loss—*psi*									
1	0.09	0.04	0.17	0.05	0.35	0.28	0.56	0.84	1.12	1.4
2	0.28	0.14	0.78	0.10	1.30	0.9	1.8	2.7	3.6	4.5
3	0.55	0.28	1.56	0.25	2.64	1.8	3.6	5.4	7.2	9.0
4	0.92	0.47	2.60	0.50	4.49	3.0	6.0	9.0	12.0	15.0
5	1.35	0.69	3.81	0.80	6.65	4.4	8.8	13.2	17.6	22.0
6	1.84	0.94	5.19	1.0	8.97	6.0	12.0	18.0	24.0	30.0
7	2.45	1.26	6.92	1.3	11.93	8.0	16.0	24.0	32.0	40.0
8	3.12	1.60	8.82	1.8	15.34	10.2	20.4	30.6	40.8	51.0
9	3.86	1.98	10.90	2.3	19.04	12.6	25.2	37.8	50.4	63.0
10	4.77	2.45	13.49	2.8	23.51	15.6	31.2	46.8	62.4	78.0

* Based on friction loss data from standard manufacturers' catalogs.
† Based on equivalent loss of 6.12 ft of $\frac{1}{2}$-in. Type K copper tubing.
‡ Based on equivalent loss of 3.14 ft of $\frac{1}{2}$-in. Type K copper tubing.
§ Based on equivalent loss of 17.3 ft of $\frac{1}{2}$-in. Type K copper tubing.
‖ Based on friction loss curve for $\frac{1}{2}$-in. Trident meter (manufactured by Neptune Meter Co., New York).

Friction Loss Data

The set of curves in Fig. 5.1–5.3 have been drawn from computed data to show the relationship between flows and friction losses in small service and meter installations. These curves have been prepared for service lengths of 20, 40, 60, 80, and 100 ft to cover normal distances from the main in the street to the building wall. Tables

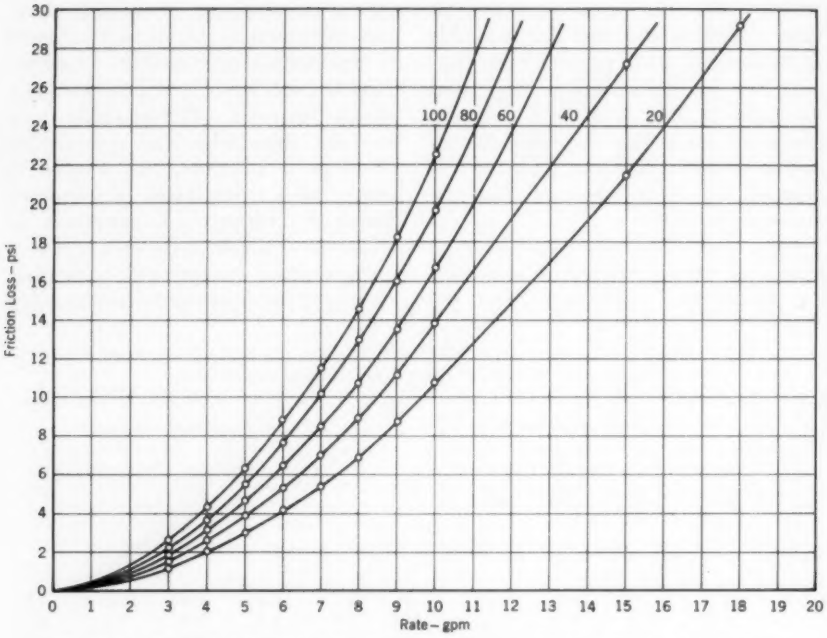


Fig. 5.2. Computed Friction Losses, ¾-in. Copper Service With ⅝-in. Meter

Numbers identifying curves indicate length of service, in feet.

TABLE 5.4

Computed Friction Losses for ¾-in. Copper Services With ⅝-in. Meter

Rate *gpm*	Service Length—*ft*				
	20	40	60	80	100
	Computed Friction Loss—*psi*				
1	0.19	0.24	0.30	0.35	0.40
2	0.55	0.72	0.89	1.06	1.23
3	1.08	1.43	1.78	2.13	2.48
4	2.03	2.61	3.19	3.77	4.35
5	3.02	3.86	4.70	5.54	6.38
6	4.06	5.22	6.38	7.54	8.70
7	5.42	6.98	8.54	10.10	11.66
8	6.82	8.72	10.62	12.52	14.42
9	8.64	11.04	13.44	15.84	18.24
10	10.73	13.73	16.73	19.73	22.73
15	21.41	27.21	33.01	38.81	44.61
20	35.61	45.01	54.41	63.81	73.21

5.2, 5.4, and 5.6 are tabulations on which Fig. 5.1–5.3 are based; Tables 5.3, 5.5, and 5.7 are the computed losses for each component part of the service installation. It will be noted that the curves include friction loss of the corporation stop; service pipe; curb stop; meter and globe valve.

Half-inch service lines are not, of course, generally installed. The data may be helpful, however, in discouraging customers from using ½-in. pipe for their portion of the service or for interior piping, except for branch lines. The curves for ¾-in. and 1-in. sizes may be used to determine approximate friction loss from the main in the street to the cellar wall of the building (including meter loss). Particular attention is called to the high friction loss through the ordinary type of globe valve usually installed by the customer at the cellar wall. Where possible, the customer should be advised to install a gate valve to reduce this loss.

It is possible to use the data sheets that accompany the curves for various combinations other than those described. For example, if the loss through a 1-in. copper service *with a ¾-in. meter* is desired, the friction loss for the 1-in. disc meter may be deducted from the total loss for 1-in. service and that of a ¾-in. meter may be substituted for it.

It should be borne in mind that the curves are based on computed values and represent optimum conditions; thus they differ from actual results. The meter friction losses, for example, are those for one particular make of meter, whereas those cited in Table 5.1 are calculated losses permissible under

TABLE 5.5

*Computed Friction Losses for ¾-in. Service Components**

Rate *gpm*	Fittings and Meter					Pipe Length—*ft*				
	¾-in. Corporation†	¾-in. Curb Stop‡	¾-in. Globe Valve§	¾-in. Disc Meter‖	Total Fittings & Meter	20	40	60	80	100
	Computed Friction Loss—*psi*									
1	0.015	0.011	0.060	0.05	0.14	0.052	0.104	0.156	0.208	0.26
2	0.050	0.034	0.195	0.1	0.38	0.17	0.34	0.51	0.68	0.85
3	0.103	0.071	0.301	0.25	0.73	0.35	0.70	1.05	1.40	1.75
4	0.170	0.117	0.664	0.5	1.45	0.58	1.16	1.74	2.32	2.9
5	0.246	0.170	0.962	0.8	2.18	0.84	1.68	2.52	3.36	4.2
6	0.340	0.234	1.33	1.0	2.90	1.16	2.32	3.48	4.64	5.8
7	0.457	0.315	1.79	1.3	3.86	1.56	3.12	4.68	6.24	7.8
8	0.557	0.384	2.18	1.8	4.92	1.90	3.80	5.70	7.60	9.5
9	0.703	0.485	2.75	2.3	6.24	2.4	4.8	7.2	9.6	12.0
10	0.879	0.606	3.44	2.8	7.73	3.0	6.0	9.0	12.0	15.0
15	1.70	1.17	6.64	6.1	15.61	5.8	11.6	17.4	23.2	29.0
20	2.75	1.90	10.76	10.8	26.21	9.4	18.8	28.2	37.6	47.0

* Based on friction loss data from standard manufacturers' catalogs.
† Based on equivalent loss of 5.86 ft of ¾-in. Type K copper tubing.
‡ Based on equivalent loss of 4.04 ft of ¾-in. Type K copper tubing.
§ Based on equivalent loss of 22.9 ft of ¾-in. Type K copper tubing.
‖ Based on friction loss curve for ¾-in. Trident meter (manufactured by Neptune Meter Co., New York).

It should be borne in mind that the curves are based on computed values and represent optimum conditions; thus they differ from actual results. The meter friction losses, for example, are those for one particular make of meter, whereas those cited in Table 5.1 are calculated losses permissible under

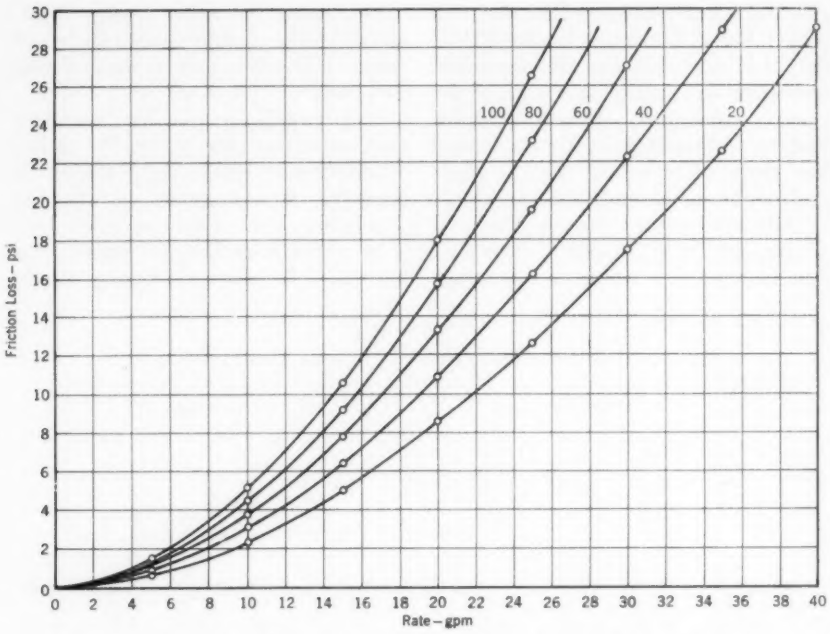


Fig. 5.3. Computed Friction Losses, 1-in. Copper Service With 1-in. Meter

Numbers identifying curves indicate length of service, in feet.

TABLE 5.6

Computed Friction Losses for 1-in. Copper Services With 1-in. Meter

Rate *gpm*	Service Length—*ft*				
	20	40	60	80	100
	Computed Friction Loss—*psi*				
5	0.7	0.9	1.1	1.3	1.5
10	2.36	3.06	3.76	4.46	5.16
15	4.94	6.34	7.74	9.14	10.54
20	8.46	10.86	13.26	15.66	18.06
25	12.57	16.07	19.57	23.07	26.57
30	17.42	22.22	27.02	31.82	36.62
35	22.6	28.8	35.0	41.2	47.4
40	28.9	36.9	44.9	52.9	60.9
45	36.7	46.7	56.7	66.7	76.7
50	44.1	56.1	68.1	60.1	92.1

AWWA standards and do not represent any particular meter. The curves should, however, be sufficiently accurate to be used as a guide in the selection of service line and meter sizes for any particular customer demand and pressure condition.

Conclusion

Reevaluation of existing practices in the sizing of service lines and meters appears to be required, particularly in view of the increasing use of water by all types of customers. This is particularly true of domestic use, which has risen greatly in the last several years. Consideration should be given to the economic aspects of the problem of pipe sizes. For example, the cost of materials is a relatively small portion of total cost of a water service installation, particularly when street paving is involved. The cost of replacing a service found to be inadequate is out of proportion with initial materials cost savings. Within reason, it is prudent to oversize services, thereby providing more flexibility in the use of meters of different sizes. Oversizing of services makes it possible to use the smallest meter consistent with demand, thereby producing more accurate measurement of low rates of flow.

Selection of service size is even more important in installations for larger customers. Although a new customer usually has little or no conception of what his water requirements will be, and, therefore, asks for much larger facilities than required, this overstatement is frequently offset within a short time by business growth and the service line capacity that was initially considered too large is found necessary. Thus, if only a larger meter is required, this change is accomplished at slight expense, as compared to the cost of service replacement if the original service is too small.

TABLE 5.7

*Computed Friction Losses for 1-in. Service Components**

Rate *gpm*	Fittings and Meter					Pipe Length—*ft*				
	1-in. Corporation†	1-in. Curb Stop‡	1-in. Globe Valve§	1-in. Disc Meter‖	Total Fittings & Meter	20	40	60	80	100
5	0.07	0.04	0.29	0.1	0.50	0.2	0.4	0.6	0.8	1.0
10	0.23	0.13	1.0	0.3	1.66	0.7	1.4	2.1	2.8	3.5
15	0.47	0.27	2.0	0.8	3.54	1.4	2.8	4.2	5.6	7.0
20	0.80	0.46	3.5	1.3	6.06	2.4	4.8	7.2	9.6	12.0
25	1.2	0.67	5.1	2.1	9.07	3.5	7.0	10.5	14.0	17.5
30	1.6	0.92	7.0	3.1	12.62	4.8	9.6	14.4	19.2	24.0
35	2.1	1.2	9.0	4.1	16.4	6.2	12.4	18.6	24.8	31.0
40	2.7	1.5	11.6	5.1	20.9	8.0	16.0	24.0	32.0	40.0
45	3.3	1.9	14.6	6.9	26.7	10.0	20.0	30.0	40.0	50.0
50	4.0	2.3	17.5	8.3	32.1	12.0	24.0	36.0	48.0	60.0

* Based on friction loss data from standard manufacturers' catalogs.
† Based on equivalent loss of 6.67 ft of 1-in. Type K copper tubing.
‡ Based on equivalent loss of 3.85 ft of 1-in. Type K copper tubing.
§ Based on equivalent loss of 29.1 ft of 1-in. Type K copper tubing.
‖ Based on friction loss curve for 1-in. Trident meter (manufactured by Neptune Meter Co., New York).

Chapter 6—Meter Installation

THE first important problem to resolve in the installation of meters for customer service is whether they are to be installed inside the customer's premises or in outdoor vaults or pits. Outdoor meter settings are made almost exclusively in the southern states, where weather during the winter is not too severe. Most homes are constructed without basements and no suitable indoor location is therefore available for installing a meter. Conversely, in the northern states, where severe winter weather conditions prevail, water meters are usually installed indoors. Between these two extremes, there is a wide area where water meters are installed in either location, depending on management judgment, experience, or preference.

Except when no suitable indoor location is available and there is therefore no choice, the selection of an outdoor location for meters appears to be made for three reasons:

1. A meter installed at the curb is placed at the point of division of utility–customer responsibility for underground service leakage. Therefore, any leakage in the customer's portion of the service line is registered by the meter.

2. Less time and expense are required in reading meters, and backcalls, which are required with indoor settings when no one is home on the normal reading date, are eliminated.

3. The utility employee is not required to enter the premises or track through the house during inclement weather, which eliminates possible customer ill will.

It should be pointed out, however, that there are a number of disadvantages to outdoor installations which, unfortunately, are not always sufficiently considered in the decision as to where meters are to be installed. This is particularly true of attempts to arrive at the probable economic result. Cost records are not usually sufficiently detailed to obtain reasonably factual data.

For example, what are the differences in costs between an outdoor meter installation and one located indoors? If the outdoor-installation cost is greater, and there is little if any doubt that it is, does the lower cost of reading alone justify the additional cost? Furthermore, how do the costs of meter installation maintenance compare? If maintenance of outdoor settings averages more than indoor, does the additional annual expense offset in whole or in part the savings in reading costs?

Results of a 1950 study of nearly 700,000 metered accounts, of which approximately 50 per cent were equipped with outdoor settings and all were read quarterly, showed that the average cost of reading a meter in an outdoor setting was $0.073. For a meter installed indoors it was $0.113. The average annual savings in reading cost was therefore $0.16 (four readings times $.04).

Capitalization of this $0.16 annual savings at 4 per cent showed that an additional investment cost for an outdoor setting of not more than $4.00 over the cost of one made indoors could be economically justified, and this did not take into account increased maintenance costs where outdoor settings were made. Adding this cost to that of reading outdoor meters, it was found the additional investment which could be supported by savings in operations was little more than $1.00. No consideration in this analysis was given to the cost of damage claims for injuries suffered from falling over or into outdoor meter boxes—which may be a considerable problem.

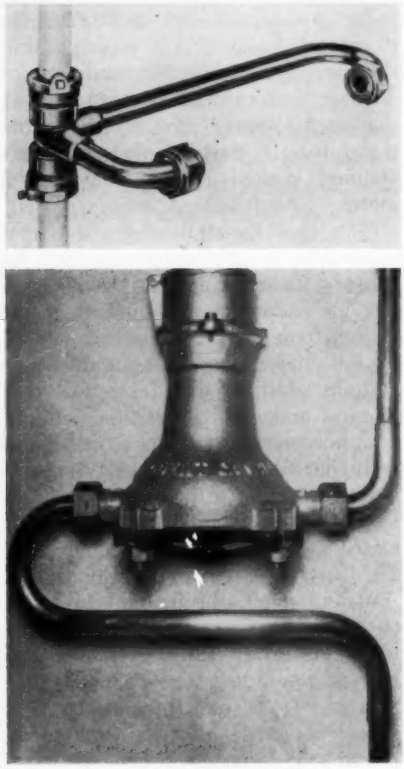


Fig. 6.1. Two Examples of Indoor Settings

In both examples, the setting is made more accessible because it may be placed in various positions.

It is not the purpose of this summary to influence a decision as to which location should be selected, but rather to point out that if basic data are available, the final conclusion may differ somewhat from original beliefs. If the cost of water service is to be controlled by exercise of considered judgment based on facts, some type of cost study is necessary before a decision is made as to where meters are to be located.

Indoor Settings

The installation of a small meter in an ordinary basement appears to be such a simple job that it is difficult to conceive of there being many improper settings. This, however, is not the case, and improper settings are often caused by lack of a detailed standard as to what constitutes an acceptable meter location. A drawing should be prepared, showing the manner in which the meter is to be installed in the house piping, with control valve or valves, *minimum* and *maximum* elevations above the cellar floor, together with suitable notation that a free, unobstructed passageway to the meter must be provided and maintained, with no partitions, coal bins, or stored material within a specified number of feet on either side of the meter. The drawing should be furnished to applicants for service and made one of the conditions for the utility's acceptance to serve any premises. Such a drawing or drawings form a firm basis for insuring proper provision for indoor installation of a water meter. Obvi-

ously, all water meters should be set in a horizontal position. If the meter is installed using meter couplings or flanges, an electrical ground wire should be required across the meter to avoid possible shock when the meter is removed from the pipeline. This jumper is a requirement of the National Electrical Code. Certain types of prepared meter settings form a continuous metallic circuit even when the meter is removed from the line. Two types of commercially available meter settings are shown in Fig. 6.1.

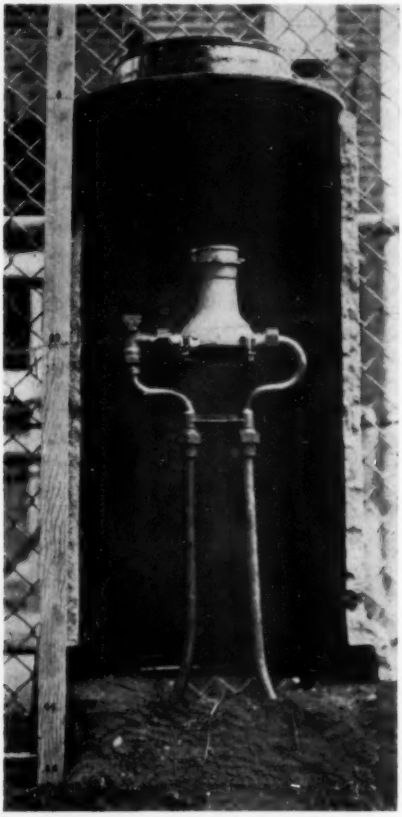


Fig. 6.2. Model Outdoor Setting

This setting, designed for maximum accessibility, is used as a model for meter installation crews to follow.

Outdoor Settings

There are numerous requisites for a satisfactory outdoor water meter installation. Of these, the important ones would include: [1] that it be constructed of durable materials to provide long life; [2] that it reduce to a minimum potential hazards of personal injury to the general public; [3] that it be so designed and constructed as to protect the meter and piping within the vault against freezing conditions or damage from external causes; and [4] that it provide ready access to the meter for the purpose of reading, installing, removing or changing the meter.

The wide variation of ground frost conditions in different sections of the country makes it impossible to detail one particular type of outdoor meter setting for small meters which has all of the major requisites listed above and, in addition, would be most economical under all conditions. In general, however, heat moves from a point of higher temperature to one of lower temperature. Furthermore, the protection against freezing in an outdoor meter vault or pit is the ground itself. As frost penetrates the ground surrounding a pit, the amount of inside surface area of warmth from the bottom and lower sides decreases and cannot counteract the colder, upper portion. If the imbalance becomes severe enough, the pipes and meter freeze. This occurs when no water is being drawn through the line. Obviously, lowering of the water temperature in the meter and piping is caused not only by the temperature of the surrounding air, but also the time

of contact. Constant movement of water out of the cold zone of the meter pit, as occurs when water is being drawn through the service line, does not permit sufficient contact time to cause the water to freeze.

A good knowledge of local conditions is necessary to select a vault or pit of sufficient size and depth to protect against freezing. For example, because frost penetrates the ground at different rates depending on the type of soil, it is quite possible to encounter no difficulty from frozen meters in one particular size of pit where installations are made in clay or good loam, whereas similar installations in sandy soil or gravel will afford relatively little protection, and meters and pipes will freeze.

Experience with outdoor installations and a study of soil conditions where meters have frozen and the freezing cannot be traced to other defects—such as broken lids or dirt washing from around the cover and causing the opening between meter box and cover to become exposed—are about the only guide that can be recommended in a manual of this type. Once it is felt that sufficient experience is available to establish standards of installation, it is recommended that a suitable sketch or sketches be prepared so that the most informed procedures are followed in making the original setting. This sketch should definitely show:

1. That the meter box cover is to be placed flush with the ground surface
2. The distance below ground surface, in inches, at which the meter spuds, or couplings, are to be located
3. That no portion of the riser piping or meter is to be less than 1–2 in. from any portion of the meter box sidewalls
4. The size or sizes of meter boxes (diameter and length) to be used for each meter size as well as each type of soil.

It is also very desirable to provide 2–4-in. clearance between the service piping and the bottom of the meter box so that if settlement of the meter box occurs, it does not damage or strain the piping or meter. Consideration should also be given to whether the curb stop (or service control valve) is to be an integral part of the meter setting or located outside of the meter box and housed in a separate curb box at additional expense. Fig. 6.2 illustrates these principles.

Large-Meter Settings

Large-meter settings, although infrequently made, introduce so many variations in piping arrangements, that it is difficult to establish any single standard. As explained in Chapter 4, however, in the selection of meters for various types of demand, the sketch and photographs of piping and meter arrangements for battery settings of 2-in. and larger meters in Chapter 4 should be referred to for what are considered to be desirable features of large-meter settings.

Suggested Titrimetric Method for Sulfate Determination

Remo Navone

A contribution to the Journal by Remo Navone, Chief, Branch Public Health Lab., Div. of Labs., State Dept. of Public Health, Los Angeles, Calif.

1. General Discussion

1.1. *Principle.* The method is based on the following facts: [1] lead sulfate is practically insoluble in an organic solvent such as ethyl alcohol; [2] an acidified solution of lead ion and dithizone forms a pink color; and [3] the addition of sulfate ion to such a solution removes the lead from the pink lead dithizonate, forming a blue-colored solution. The endpoint of the titration occurs when the alcoholic solution assumes a blue color free from all traces of a violet tinge. The color change during the course of the titration is from pink to violet to blue. The occurrence of the endpoint is a function of the pH of the titrated solution; therefore, a standard sulfate solution is used to check the titration endpoint, as will be described. The conditions given in the procedure provide a pH of about 3.0 during titration, which is found to be satisfactory.

1.2. *Interference.* Calcium ion interferes in this procedure and is removed from the sample by means of ion exchange. The ion-exchanger resin is a strong cation exchanger in the hydrogen form, thereby exchanging the cations in the solution with the hydrogen ions from the resin. The sample freed from the resin by filtration is placed in a buret and used as a titrant for titrating a given concentration of lead ion. Chloride ion does not interfere with this procedure in concentrations up to 300 mg/l. Fluoride ion at 5 mg/l does not interfere; however, phosphate ion (PO_4^{---}) above 0.5 mg/l does interfere, giving high sulfate values.

2. Apparatus

2.1. *Magnetic stirrer,* or any other stirrer with controlled speed.

2.2. *Buret,* 10-ml, graduated in 0.05-ml steps.

2.3. *Short-stem filter funnel.*

2.4. *Filter paper,** 12.5 cm, folded.

3. Reagents

3.1. *Acidified dilution water,* prepared by adding 20 ml concentrated HNO_3 to 1,980 ml distilled water.

3.2. *Sulfate standard,* prepared by dissolving 181.4 mg of dry K_2SO_4 in distilled water to make a 1,000-ml solution. One milliliter of this standard contains 0.100 mg SO_4^{--}.

3.3. *Lead nitrate solution,* 0.0200*N*, prepared by dissolving 1.6561 g of dry $Pb(NO_3)_2$ in 200 ml of the acidified dilution water, and then adding more

* Such as S & S No. 588; manufactured by Schleicher & Schnell Co., Keene, N.H.

TABLE 1

Normality of Lead Solution to Use With Concentrations of Sulfate Ion

Sulfate Concentration mg/l	Lead Solution
0–25	0.005*N*
15–100	0.01*N*
100–500	0.02*N*

acidified dilution water to make a 500-ml solution. Dilutions of this standard may be made when needed, but the acidified dilution water must be used.

3.4. *Dithizone indicator,* prepared by dissolving 0.10 g crystalline dithizone in 100 ml chloroform. This reagent should be kept in a refrigerator when not in use.

3.5. *Ethyl alcohol,* 90 per cent.

3.6. *Cation-exchange resin* * (hydrogen form), analytical grade, air dried.

4. Procedure

4.1. *Standardization steps.* In a 100-ml beaker, measure out about 50 ml of the sulfate standard. Add 2.0 g of the resin and stir the mixture at moderate speed for 10–15 min. While the ion exchange is taking place, add to a 250-ml erlenmeyer flask 100 ml of 90 per cent ethyl alcohol and, with a volumetric pipet, 1 ml of standard lead solution (see Table 1 for normality to use). Swirl flask to mix and then add 0.1 ml of the dithizone solution. Contents of the flask will have the pink color typical of the lead dithizonate complex. When the ion-exchange step is complete, filter off the resin and pour filtrate into the 10-ml buret. Titrate into the erlenmeyer flask, swirling the contents until the color changes to light violet; then titrate dropwise with continued swirling until the blue color of the endpoint is reached. Read the buret, then add one or two more drops to make sure of no further color change. Titration should be made in good light and the color of the solution observed by viewing through the solution with the flask held near a white background.

4.2. *Titration of sample.* A 50-ml portion of water sample is treated in the same manner as the standard sulfate solution in the standardization step outlined in 4.1.

5. Calculation

$$\frac{1{,}000A\,(V_2)}{V_1} = \text{mg/l}\ SO_4^{--}$$

in which: V_1 is the volume (in milliliters) of water sample used in titration; V_2 is the volume (in milliliters) of sulfate standard used in titration; A is milligrams of sulfate ion per milliliter of standard sulfate solution.

TABLE 2

Comparison of Data From Titrimetric and Gravimetric Analyses

Sample No.	Gravimetric Sulfate mg/l	Titrimetric Sulfate mg/l
1	41.0	42.4
2	490	496
3	188	192
4	490	490
5	413	413
6	299	302
7	44.2	44.9
8	149	150
9	226	223
10	181	182
11	20.0	18.3
12	765	762

* Similar to Amberlite IR-120H; manufactured by Rohm & Haas Co., Philadelphia, Pa.

If 1 ml of sulfate standard contains 0.100 mg SO_4^{--}, this equation reduces to:

$$\frac{100(V_2)}{V_1} = \text{mg/l } SO_4^{--}$$

6. Precision and Accuracy

The data in Table 2 indicate that the average deviation of sulfate values obtained by this procedure compared to the gravimetric analysis is 2.1 mg/l. The results obtained are therefore comparable to the gravimetric procedure for sulfate determination described in the tenth edition of *Standard Methods* (*1*), and are obtained in ½ hr or less, compared to the 3 hr or more required by the gravimetric procedure.

Reference

1. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.* APHA, AWWA & FSIWA, New York (10th ed., 1955). p. 196.

Correction

The article by Ralph E. Noble and Marvin Reitman, "Influence of Basic Fuchsin and Sodium Sulfite on EHC Endo Membrane Filter Medium" (May 1959 JOURNAL, Vol. 51, pp. 614–622), contained three editorial errors. On p. 615, in col. 2, lines 22–23, the word "multitude" should read "multitube." On p. 619, in col. 2, line 6, the word "ordinate" should be "abscissa"; conversely, in line 11, the word "abscissa" should be "ordinate."

Suggested Amperometric Titration Method for Sulfide Determination

Eugene Goldman

A contribution to the Journal by Eugene Goldman, Chemist, Dept. of Water & Power, Los Angeles, Calif.

1. General Discussion

The amperometric titrator is widely used in the determination of residual chlorine. The following method utilizes the instrument in a back-titration determination of sulfide. This procedure is a substantial simplification over the methylene blue colorimetric method and more sensitive than the conventional iodine titration method. By increasing reagent concentrations, the method should be adaptable to ranges of sulfide found in polluted waters, but as presented here, it is designed for waters free of gross pollution. Sampling techniques as outlined in the tenth edition of *Standard Methods* (*1*) should be followed. The method has been successfully used in the 0–0.20-ppm range and can be adapted for use on samples in which sulfide has been precipitated with zinc acetate.

2. Apparatus

Amperometric titrator.*

3. Reagents

3.1. *Phenylarsenoxide solution,* 0.00564*N*. Dissolve approximately 0.8 g C_6S_5AsO powder in 150 ml 0.3*N* NaOH. After settling, decant 110 ml of this solution into 800 ml distilled water and mix thoroughly. Bring the solution to pH 6–7 with dilute HCl solution, and finally dilute to 1 liter. Titrate with freshly standardized iodine solution using starch indicator, and finally adjust with distilled water to 0.00564*N*.†

3.2. *Stock iodine solution,* 0.025*N*. Weigh out 3.175 g iodine into a weighing bottle containing distilled water and 25 g KI. Slowly dilute to 1 liter.

3.3. *Iodine working solution,* 0.001*N*. Dilute 20.000 ml of Solution 3.2 to 1.000 liter in a volumetric flask.

3.4. *pH 4 buffer.* Dissolve 480 g glacial acetic acid and 243 g $NaC_2H_3O_2 \cdot 3H_2O$ in 400 ml distilled water, and dilute to 1.000 liter.

4. Procedure

4.1. To 200 ml of sample, add 10.00 ml of iodine working solution and 1 ml of pH 4 buffer.

4.2. Titrate to the endpoint with standard phenylarsenoxide, according

* Such as that made by Wallace & Tiernan Inc., Belleville, N.J.

† This solution is prepared the same way for residual chlorine determination. The method of preparation is quoted from the tenth edition of *Standard Methods,* p. 75.

to the instrument-operating instructions, and record the volume of titrant used.

4.3. Add an additional 10.00 ml of iodine working standard, and again titrate with phenylarsenoxide. Record the volume of titrant used.

5. Calculation

mg/l sulfide = 0.45 [(ml titrant in 4.3) − (ml titrant in 4.2)]

Reference

1. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes.* APHA, AWWA & FSIWA, New York (10th ed., 1955).

Reprints Available

Reprints of the following articles, published in the JOURNAL during the preceding year, will be available from the Association in small quantities, at the prices noted, until the present stock is exhausted. Order by reprint number and author's name from: Order Dept., American Water Works Assn., Inc., 2 Park Avenue, New York 16, N.Y. **Prepayment required on orders under $2.** (Note: This list does not include standards and similar documents kept permanently in stock.)

Reprint No.	Author	Title	Issue of JOURNAL	No. of Pages	Price per Copy
R804	RENSHAW, BOHANAN	Irrigation Water	Mar 58	17	30¢
R805	COMMITTEE REPORT	Water Hammer Allowances	Mar 58	16	25¢
R806	LADUE	Manager's Responsibilities	Mar 58	6	20¢
R807	BARTHOLOMEW, SILVEY	Odor Control With Copper	Apr 58	8	20¢
R808	MARTIN, WHITE	Vehicular Safety	Apr 58	7	20¢
R809	AWWA POLICY	Reservoir Recreational Use	May 58	2	15¢
R812	TASK GROUP REPORT	Artificial Recharge	Jul 58	7	20¢
R813	THOMAN & JENKINS	1956 USPHS Survey	Aug 58	7	20¢
R814	METZIGER, GULLANS, STAFF REPORT	Fluoride Availability	Aug 58	10	25¢
R815	WEBB, HICKMAN, ALLEN	Safety Programs	Aug 58	18	30¢
R818	PANEL DISCUSSION; WOLMAN	Water Rights Law	Oct 58	18	30¢
R819	CONWAY	Fluoridation Law	Oct 58	7	20¢
R820	TASK GROUP REPORT	Domestic Water Use	Nov 58	11	25¢
R821	PANEL DISCUSSION	Plastic Pipe	Nov 58	14	25¢
R824	COMMITTEE REPORT	Backflow Preventers	Dec 58	32	45¢
R901	PANEL DISCUSSION	Chlorine Residuals	Feb 59	19	30¢
R902	SEEGER & WALSH	Extension Problems	Mar 59	9	25¢

AWWA C500–59T

American Water Works Association
New England Water Works Association

TENTATIVE
AWWA STANDARD
for
GATE VALVES FOR ORDINARY WATER WORKS SERVICE

This "Standard for Gate Valves for Ordinary Water Works Service" is based upon the best known experience and is intended for use under normal conditions. It is not designed for unqualified use under all conditions and the advisability of its use for any installation must be subjected to review by the engineer responsible.

First Edition approved as "Tentative" May 9, 1952; revised Jun. 2, 1952.
Second Edition approved as "Tentative" Jan. 28, 1959.

● **Price of reprints—25¢ per copy**

● **Approximate date available—Sep. 15, 1959**

AMERICAN WATER WORKS ASSOCIATION
Incorporated
2 Park Avenue, New York 16, N.Y.

Prepared by

Water Works Practice Committee 8530 D

DAVID AULD, *Chairman*

CARL F. BUETTNER
KENNETH J. CARL
A. C. MICHAEL
HUBERT F. O'BRIEN
LESLIE PAUL
CARL H. SIMON
J. SAMUEL SLICER JR.
LORING E. TABOR

Table of Contents

	Section
Scope	1
Valve Pressure Ratings	2
Conditions Not Covered	3
Information to Be Supplied by Purchaser	4
Data to Be Furnished by Manufacturer	5
Materials	6
General Design	7
Bodies and Bonnets	8
Bonnet Bolting	9
Valve Ends	10
Gates and Rings	11
Body-Seat Rings	12
Wedging Device	13
Guides (Wedge Gate Valves)	14
Rollers and Tracks for Horizontal Valves	15
Stems and Stem Nuts	16
Stem Seal	17
Packing	18
Glands and Gland Bolts and Nuts	19
Wrench Nuts	20
Gearing	21
Gear Cases	22
Indicators	23
Bypasses	24
Gaskets	25
Workmanship	26
Painting	27
Markings	28
Testing	29
Inspection and Rejection	30
Preparation for Shipment	31
Notes	*following* 31

© *Copyright 1952 and 1959 by the American Water Works Association, Inc., as part of the September 1952 and July 1959 issues of Journal AWWA*

Made in USA

Latest Revisions to C500

This Second Edition of AWWA C500 contains extensive revisions approved Jan. 28, 1959. The document retains its "Tentative" status. All printings of the First Edition are obsolete.

Designation. As a result of the revision, the former designation, C500–52T, has been changed to C500–59T.

AWWA C500–59T

Tentative AWWA Standard for

Gate Valves for Ordinary Water Works Service

Foreword

This standard is intended to assist purchasers in obtaining gate valves suitable for ordinary water works service and includes, directly or by reference, stipulations concerning materials. The standard provides dimensions for bell and flanged ends of valves and includes all dimensional information that is essential to uniformity of production.

Sec. 1—Scope

This standard covers iron-body, bronze-mounted valves intended for use in approximately level setting on buried pipelines in municipal water distribution systems. Valves covered by this standard include: double-disc gate valves with nonrising stems (Fig. 1 and 2*), having either parallel or inclined seats, and solid-wedge gate valves with nonrising stems (Fig. 2*).

Sec. 2—Valve Pressure Ratings

Valves shall be designed for operation at working water pressures of not less than 175 psi for valve diameters of 3–12 in., inclusive, and 150 psi for valves of 16–48 in., inclusive. Operating pressures or sizes of valves which fall outside these limits are beyond the intended scope of this standard and require special consideration in design and construction.

* See "Notes" following Sec. 31.

Sec. 3—Conditions Not Covered

This standard is not intended to cover special conditions of installation or operation—such as built-in power drive; installation in vertical or steeply inclined lines; conveyance of water of unusual corrosivity (pH less than 5); excessive water hammer; frequent operation, as in filter service; or operation in throttled position. Such conditions are beyond the intended scope of this standard and require special consideration in design and construction.

Sec. 4—Information to Be Supplied by Purchaser

In placing orders for valves to be manufactured in accordance with this standard, purchasers should specify the following details:

4.1. Standard used—that is, AWWA C500.

4.2. Size of valve.

4.3. Quantity required.

4.4. Type of valve as specified under Sec. 1.

4.5. Whether records of tests are to be furnished as specified under Sec. 6.2.

4.6. Type of valve ends—bell, flanged, or mechanical joint, as specified under Sec. 10.

4.7. Detailed description of end connections, if dimensions are to be other than as specified in Sec. 10.

4.8. Class or outside diameter of pipe to be used with valves 30 in. or larger, as specified under Sec. 10.

4.9. Intended position of valve in line—that is, horizontal or vertical.

4.10. Solid-bronze discs (gates), if required, as specified under Sec. 11.5.

4.11. Type of stem seal—stuffing box or O-ring.

4.12. Detailed description of wrench nuts, if not in accordance with Sec. 20.

4.13. Direction in which wrench nut shall turn to open—whether right (clockwise) or left (counterclockwise).

4.14. Gears, if required, as specified under Sec. 21.

4.15. Cast-iron gears, if required, as specified under Sec. 21.2.

4.16. Whether gear cases are not to be provided, as specified under Sec. 22.

4.17. Position indicator, if required, as specified under Sec. 23.

4.18. Bypass, if required, as specified under Sec. 24. Unless otherwise specified, the position of the bypass on the valve body shall be as shown in Fig. 3, Position A or B.

4.19. Spot-facing, if required, as specified under Sec. 26.2.

4.20. Special cast markings, if required, as specified under Sec. 28.1.

4.21. Whether the piping system in which the valve or valves are to be used carries water that has been softened or promotes galvanic corrosion as described in the footnote of Sec. 6.5.

4.22. Manufacturer's record of tests, if required, as stated under Sec. 30.2.

4.23. What alternate, if any, is desired, as noted in:

Sec. 9—type of rustproofing, if not cadmium or zinc coated

Sec. 13.2—monel wedging device, if offered by manufacturer

Sec. 19.2—type of rustproofing of glands.

Sec. 5—Data to Be Furnished by Manufacturer

5.1. After purchase of the valve, the manufacturer shall, if requested, furnish catalog data, including illustrations, and a parts schedule giving the materials of which parts are made, in sufficient detail to serve as a guide in the assembly and disassembly of the valve, as well as in ordering repair parts.

5.2. When required, the manufacturer shall furnish a statement of the total net assembled weight for each size of valve.

5.3. When required, the manufacturer shall submit for approval by the purchaser one set of certified drawings, showing the principal dimensions, construction details, and materials used for all parts of the valve. All work shall be done, and all valves shall be furnished, in accordance with these certified drawings, after they have been approved by the purchaser.

Sec. 6—Materials

6.1. *General.* All materials designated hereinafter, when used in valves produced under this standard, shall conform to the standards designated for each material listed. When reference

is made to American Standards Association (ASA), American Society for Testing Materials (ASTM), or other standards, it is understood that the latest revision thereof shall apply.

6.2. *Physical and chemical properties.* The requirements of ASA, ASTM, or other standards to which reference is made elsewhere in this document shall govern the physical and chemical characteristics of the valve components.

6.3. *Tests.* Whenever valve components are to be made in conformance with ASA, ASTM, or other standards which include test requirements or testing procedures, such requirements or procedures shall be met by the valve manufacturer. The records of such tests shall, if required by the purchaser, be made available to him.

6.4. *Cast iron.* Cast iron shall conform to ASTM A126.

6.5. *Bronze.** Grade I cast bronze shall conform to ASTM B62. Grade II cast bronze shall conform to ASTM B132, Alloy A. Grade III cast bronze shall conform to ASTM B132, Alloy B. Grade IV rolled bronze shall conform to ASTM B21, Alloy A (half-hard). Grade V bronze shall be sufficiently malleable to conform to dovetailed grooves when peened or rolled, and shall have a minimum compressive strength, without permanent deformation, of 4,000 psi. Grade VI cast aluminum bronze shall conform to ASTM B148; Grade VI forged aluminum bronze shall conform to ASTM B150.

6.5. *Steel.* Body bolts and nuts shall conform to ASTM A307, Grade B. Carbon steel castings, when used, shall conform to ASTM A27, Grade U60-30.

6.6. *Babbitt.* Babbitt metal shall conform to ASTM B23.

Sec. 7—General Design

7.1. *Resistance to stress.* All parts of all valves shall be designed to withstand safely, without structural damage, both [1] the stresses resulting from an internal test pressure of 300 psi and [2] the combined stresses resulting from the full, internal working water pressure as specified under Sec. 2, when the wedge or gates move across the seats, under full unbalanced working water pressure from the fully closed position to the point of opening; thence to complete closure.

7.2. *Basis of structural design.* In order to allow a repair to be made without the necessity of removing the valve from the line, all parts, including the body and bonnet, shall be so proportioned that if excessive torque is applied to the stem in the closing direction with the valve disc seated and subjected to the working water pres-

* Grades II, III, and IV bronze shall not be used in waters that promote galvanic corrosion (that is, waters with higher pH than 9 or with a specific conductance of more than $350K \times 10^6$ micromhos), as such water will remove zinc from the bronze. In such water, the bronze used shall not contain more than 15 per cent zinc or more than 2 per cent aluminum. Alternative materials meeting the following physical limits and acceptable to the manufacturer and purchaser must be used with such waters:

Bronze	Minimum Tensile Strength *psi*	Minimum Yield Strength *psi*	Minimum Elongation in 2 in. *per cent*
Low strength	30,000	14,000	20
Medium strength (stems for valves 24 in. and smaller)	45,000	20,000	15
High strength (stems for valves 30 in. and larger)	60,000	32,000	10

sure, failure of the pressure-retaining parts (such as the valve body or bonnet) shall not occur.

7.3. *Size of waterway.* With the valve open, an unobstructed waterway shall be afforded, the diameter of which is not to be less than the full nominal diameter of the valve, except that, if lugs are provided for inserting or removing the body-seat rings, they need not be removed after the valve is assembled.

Sec. 8—Bodies and Bonnets

8.1. It is recognized that some variations are unavoidable in the making of patterns and castings. In order to define what may be considered a reasonable degree of accuracy in shell thickness measurements, the following inspection limits shall govern:

Shell thickness measurements taken at points diametrically opposite to each other shall, when added together and divided by two, equal or exceed the minimum metal thicknesses given in Table 1. Shell thicknesses at no point shall be more than 12.5 per cent below the minimum metal thicknesses called for in Table 1, and no continuous area of deficient thickness shall exceed 12.5 per cent of the superficial area of the casting.

8.2. All metal sections and ribbing shall be properly proportioned, and corners shall have well rounded fillets, in accordance with good foundry practice. In double-disc gate valves, the body and bonnet shall be designed to reduce the side clearance of the discs.

8.3. The valve body shall be machined and threaded for shoulder-seated (or bottom-seated) body-seat rings, and the thread shall be sufficiently deep and the seating surface sufficiently accurate to prevent leakage behind the body-seat rings.

8.4. The thrust-bearing recess and the stem opening (if the latter is in contact with the stem) in the bonnet shall have a smooth, machined finish. In valves 16 in. in diameter and larger, the thrust-bearing surface shall be Grade I or II bronze, and the stem opening shall be Grade I or II bronze-bushed (if the latter is in contact with the stem).

8.5. In horizontal-stem valves 16 in. in diameter and larger, and in vertical-stem valves 24 in. in diameter and larger, a pair of accurately matched dowel holes and tapered or round-end dowels shall be provided in the flanges of the body and bonnets to aid in assembling. Dowels shall be located at opposite ends of the flange—one near the lateral center line, and the other approximately 2 in. from the lateral center line.

8.6. Bodies and bonnets of valves 10 in. and larger in size shall be made of cast iron of not less than Class B ma-

TABLE 1

Minimum Thickness of Bodies and Bonnets

Valve Diameter *in.*	Minimum Thickness* *in.*
3	0.37 ($\frac{3}{8}$)
4	0.40 ($\frac{13}{32}$)
6	0.43 ($\frac{7}{16}$)
8	0.50 ($\frac{1}{2}$)
10	0.63 ($\frac{5}{8}$)
12	0.68 ($\frac{11}{16}$)
16	0.85 ($\frac{27}{32}$)
20	0.97 ($\frac{31}{32}$)
24	1.08 ($1\frac{5}{64}$)
30	1.39 ($1\frac{13}{32}$)
36	1.54 ($1\frac{17}{32}$)
42	1.58 ($1\frac{19}{32}$)
48	1.73 ($1\frac{23}{32}$)

* The decimal value should be used when the two expressions are not exactly equivalent. The figures listed are taken from ASA A21.2 (AWWA C102), standard for cast-iron pit-cast pipe for water or other liquids. Thicknesses of valves up to and including 36 in. are the same as those specified for Class 250 pit-cast pipe. Thicknesses of 42- and 48-in. valves are the same as those specified for Class 200 pit-cast pipe.

terial as specified in ASTM A126. Bodies and bonnets of valves less than 10 in. in size shall be made of cast iron of quality not less than Class A material as specified in ASTM A126.

Sec. 9—Bonnet Bolting

Body bolts, studs, and nuts shall conform to ASTM A307, Grade B. Bolts, studs, and nuts shall be [1] cadmium plated or zinc coated (ASTM A123) or [2] rustproofed by some other process (such as parkerizing or sherardizing), disclosed to, and acceptable to, the purchaser.

Sec. 10—Valve Ends

10.1. *Ends for bell-and-spigot pipe.* Valves designed for installation with bell-and-spigot pipe shall be cast with bells on each end. The dimensions of the bells on valves up to and including 24 in. in diameter shall conform to those for Class D * pressure fittings, as required by AWWA C100. On valves 30 in. and larger in size, either the bell dimensions, the class, or the outside diameter of the pipe to be used shall be specified by the purchaser.

10.2. *Ends for flanged pipe.* The end flanges of flanged gate valves shall conform in dimensions and drilling to ASA B16.1 for cast-iron flanges and flanged fittings, Class 125, unless explicitly provided otherwise in the supplementary specifications.

* AWWA C100 Class D Bell Diameter:

Size of Pipe *in.*	ID of Bell *in.*
4	5.70
6	7.80
8	10.00
10	12.10
12	14.20
16	18.80
20	23.06
24	27.32

10.3. *Ends for mechanical-joint pipe.* When a valve is to be connected to mechanical-joint pipe, the bell dimensions shall conform to Table 11.1 of AWWA C111 (ASA A21.11). Slots, with the same width as the diameter of the bolt holes, may be provided instead of holes in the bell flange at those places near the top of the joint where the valve body or bonnet interferes with the joint assembly.

Sec. 11—Gates and Rings

11.1. Cast-iron gates shall be so fitted with separate rings as to preclude loosening or leaking behind the seats, and shall have a cross section stiff enough to resist accidental deformation in handling and assembly.

11.2. Gate rings shall be rolled, peened, or pressed into grooves machined in the discs or fastened by some other method disclosed to, and acceptable to, the purchaser.

11.3. Smooth, machine-finished cuts shall be taken over the gate rings after they have been fully secured in place.

11.4. The width of the face of the gate rings shall not be less than that of the body-seat rings, and there shall be provided a sufficiently greater width to permit the gates to continue to seat tightly after allowance for reasonable wear of the faces of the rings, and of the various parts of the mechanism of the gate.

11.5. Valve gates shall be cast iron or Grade I bronze at the manufacturer's option, unless bronze is explicitly required by the purchaser's supplementary specifications. Gate rings shall be made of Grade V bronze.

Sec. 12—Body-Seat Rings

12.1. Body-seat rings shall be backfaced, with threads accurately cut, and

the rings shall be screwed into machined seats in the body. The face in contact with the gate seat ring shall be smooth, machine finished. The rings shall be made with a cross section stiff enough to resist accidental deformation in handling and assembly.

12.2. The width of body-seat rings shall be sufficient to result in a bearing pressure of the gate on the body-seat ring of not more than 2,000 psi under the hydrostatic pressure of 300 psi. The thickness of the body-seat ring shall be not less than 20 per cent of the width of the face as calculated from the above requirement.

12.3. Body-seat rings shall be made of Grade I bronze.

Sec. 13—Wedging Device

13.1. Gate valves of the double-disc type shall be equipped with a free and positive-operating internal wedging device, simple and rugged in design, which, in closing the valve, will (when the discs cover the ports) press the discs firmly against the body seats and release the wedging load therefrom before both discs start to move.

13.2. Bronze used for wedges shall be Grade I, II, or III. Pins and bolts in the wedging mechanism of all valves shall be Grade IV bronze. In valves 16 in. in diameter and larger, all wedging surfaces shall be Grade I, II, or III bronze to bronze; in valves of diameters 3–12 in., inclusive, all wedging surfaces may be Grade I, II, or III bronze to iron, but not iron to iron. At the manufacturer's option (subject to purchaser's approval), copper-nickel alloy or monel made to Navy Specification 46MI may be used for wedging surfaces instead of Grade I bronze.

Sec. 14—Guides (Wedge Gate Valves)

14.1. In solid-wedge gate valves, tongue-and-groove guides shall be provided on the sides of the gate and in the body to keep the gate centered between the seats throughout its length of travel.

14.2. In valves 16 in. in diameter and larger, bearing of gate on guides shall have length equal to at least 50 per cent of the port diameter of the valves, and the grooves in the gate shall be Grade I, II, III, or IV bronze-faced to bear against the guides in the body; guide contacts shall be Grade I, II, III, or IV bronze to bronze.

Sec. 15—Rollers and Tracks for Horizontal Valves

15.1. *Double-disc valves.* Gate valves of double-disc type, 16 in. in diameter and larger, designed to lie horizontally in a horizontal pipeline, shall be equipped with solid-bronze (Grade I or IV) or hard-babbitt tracks securely fastened in body and bonnet. The weight of the gates shall be carried on rollers throughout their entire length of travel. Babbitt metal for tracks shall conform to ASTM B23, Grade 3.

15.1.1. In double-disc gate valves of the rolling-disc type, the discs shall serve as rollers.

15.1.2. In double-disc valves of other than the rolling-disc type, the discs shall be carried on solid-bronze (Grade I, II, III, or IV) rollers securely attached to them.

15.2. *Wedge gate valves.* In gate valves of the solid-wedge type, 16 in. in diameter and larger, designed to lie horizontally in a horizontal pipeline, the tongue-and-groove gate guides

TABLE 2

Minimum Diameter of Stem and Minimum Number of Turns to Open

Diameter of Valve *in.*	Min. Diam. of Stem at Base of Thread *in.*	Min. No. of Turns to Open
3	0.8594	10
4	0.8594	12
6	1.000	18
8	1.000	24
10	1.125	30
12	1.188	36
16	1.438	48
20	1.750	40
24	1.969	48
30	2.188	60
36	2.50	72
42	2.75	84
48	3.50	96

shall be modified with rollers or shoes to carry the weight of the wedge throughout its length of travel on solid-bronze (Grade I or IV) or hard-babbitt tracks securely fastened in the body and bonnet. Babbitt metal shall conform to ASTM B23, Grade 3.

15.3. *Scrapers.* In all valves in which rollers and tracks are used, bronze scrapers (Grade I, II, III, or IV) shall be provided to traverse the tracks ahead of the rollers in both directions of travel to remove any foreign matter which may have accumulated on the track.

Sec. 16—Stems and Stem Nuts

16.1. All stem collars shall be made integral with stems.

16.2. The threads of stems and stem nuts (disc bushings) shall be of Acme, modified Acme, or one-half V type, with a sufficient number of cuts to avoid straining the metal.

16.3. Stems shall be turned and threaded straight and true, and shall work true and smooth and in perfect line throughout the lift of opening and thrust of closing the valve.

16.4. The diameters of stems at the base of the thread shall be not less than those shown in Table 2.

16.5. Stems in valves up to and including 16 in. in diameter shall have a lead of not more than $\frac{1}{3}$ in. Stems in valves 20 in. and larger shall have a lead of not more than $\frac{1}{2}$ in. (See Table 2 for minimum number of turns to open.)

16.6. Valve stems shall be cast, forged, or rolled bronze. Bronze for cast stems shall be Grade II, III, or VI for valve sizes 24 in. and smaller, and Grade III or VI for valve sizes 30 in. and larger. Bronze for forged and rolled stems shall be Grade II, IV, or VI with physical characteristics equal to or better than shown in Table 3. Stem nuts shall be Grade I, II, or III bronze.

Sec. 17—Stem Seal

17.1. Design of the stuffing box shall be such that the valve can be packed under pressure when in the fully open position.

17.2. The stem opening, thrust-bearing recess, and bonnet face of the

TABLE 3

*Physical Characteristics of Manganese Bronze**

	Minimum Tensile Strength *psi*	Minimum Yield Strength *psi*	Minimum Elongation in 2 in. *per cent*
Valve sizes 24 in. and smaller	60,000	20,000	15
Valve sizes 30 in. and larger	80,000	32,000	15

* For use in forged and rolled stems.

stuffing box shall be smooth, machine finished. In valves 16 in. in diameter and larger, both the stem opening and thrust-bearing recess shall be Grade I, bronze bushed.

17.3. Stuffing boxes shall have a depth not less than the diameter of the valve stem. The internal diameter shall be large enough to contain adequate packing to prevent leakage around the stem.

17.4. When an O-ring or other pressure-actuated stem seal is used, the design shall incorporate two such seals, the dimensions of such seals to be in accordance with Military Specification MIL-P-5514.

17.5. The O-ring stem seal shall be so designed that the seal above the stem collar can be replaced with the valve under pressure in full-open position.

17.6. The stuffing box shall be made of cast iron. Bronze for the stem collar, thrust bushings, and stem opening, if bushed, shall be Grade I. Stem seal bolts and nuts shall conform to ASTM A307, Grade B. They shall be rustproofed as is required for body bolts and nuts in Sec. 9.

Sec. 18—Packing

18.1. *Material.* Stuffing box packing shall be made of asbestos conforming to Navy Department Specification 33-P-26-b, Type A, or flax packing conforming to Federal Specification HH-P-106c. Hemp or jute packing shall not be used.

18.2. *Installation.* Stuffing boxes shall be properly packed and ready for service when valves are delivered to the purchaser.

Sec. 19—Glands and Gland Bolts and Nuts

19.1. The gland assembly shall be of solid, solid-bushed, or two-piece design. Gland flanges (followers) may be formed as a flanged end on the gland, or as a separate part.

19.2. Glands for valves of sizes 12 in. and smaller shall be made of Grade I, II, III, IV, or ASTM B124 bronze. Glands for valves of sizes larger than 12 in. may be made of iron with bushings of Grade I, II, III, IV, or ASTM B124 bronze; iron glands which are either [1] cadmium plated or zinc coated (ASTM A123) or [2] rustproofed by some other process, such as parkerizing or sherardizing, disclosed to, and acceptable to, the purchaser, may be furnished.

19.3. If a gland flange (follower) is used, it shall be made of either cast iron or bronze of a corresponding grade of material specified in Sec. 19.2 for glands.

19.4. Gland bolts shall be made either of Grade II or IV bronze or rustproofed steel according to Sec. 9. Gland bolt nuts shall be made of Grade II, III, or IV bronze.

Sec. 20—Wrench Nuts

20.1. Wrench nuts shall be fitted to the top of the valve stem, and secured in position by nut, pin, or key.

20.2. Unless otherwise explicitly required by the purchaser's supplementary specifications, the wrench nuts shall be $1\frac{15}{16}$ in. square at the top, 2 in. square at the base, and $1\frac{3}{4}$ in. high. Nuts shall have a flanged base upon which shall be cast an arrow at least 2 in. long showing the direction of opening, and the word "OPEN," in $\frac{1}{2}$-in. or larger letters, shall be cast on the nut to indicate clearly the direction to turn the wrench when opening the valve.

20.3. The flanged base of the nut may be shaped or cut away to permit access from the ground surface to the

packing gland bolts with an extension socket wrench.

20.4. The operating nuts on all right-hand-opening (clockwise) valves shall be painted red, and the operating nuts on all left-hand-opening (counter-clockwise) valves shall be painted black.

20.5. Wrench nuts shall be made of cast iron.

Sec. 21—Gearing

21.1. Gears shall be accurately formed and smooth running, with bronze spindles running in bronze, or with babbitt-lined bearings. Gear teeth shall be machine cut. Gear ratios shall not be less than those shown in Table 4.

TABLE 4

Gear Ratios

Valve Diameter *in.*	Gear Ratio
16	2:1
20	2:1
24	2:1
30	3:1
36	3:1
42	4:1
48	4:1

21.2. Geared valves shall be equipped with cut-tooth steel gears, unless cut-tooth cast-iron gears are explicitly required by the purchaser's supplementary specifications. Pinions with cast-iron gears shall be steel. Material for steel gears shall conform to the physical requirements of ASTM A27, Grade U60-30. Babbitt lining for bearings shall conform to ASTM B23, Grade 8.

Sec. 22—Gear Cases

When geared valves are furnished, enclosed gear cases are required unless definitely excluded by the purchaser's supplementary specifications. Two types may be furnished—the extended type or the totally enclosed type. The extended type shall be attached to the bonnet of the valve in such manner as to permit repacking of the stuffing box of the valve without disassembly. The totally enclosed type shall be attached to the bonnet to enclose both stuffing box and gearing.

Sec. 23—Indicators

When required by purchaser's supplementary specifications, geared valves shall be equipped with indicators to show the position of the gate in relation to the ports. The indicator mechanism shall be all bronze, enclosed in a dirt-proof, cast-iron case, and mounted in such a position that the indicator can be easily seen by the man operating the valve.

TABLE 5

Size Requirements of Bypasses

Valve Diameter *in.*	Bypass Diameter *in.*
16–20	3
24–30	4
36–42	6
48	8

Sec. 24—Bypasses

Bypasses, when required by the purchaser's supplementary specifications, shall be of the sizes shown in Table 5 and shall be located in one of the positions indicated in Fig. 3. Bypass valves shall be the same size as the bypass and shall conform to the requirement of this standard for the specific valve size used.

Sec. 25—Gaskets

25.1. Gaskets shall be full cut, with holes to pass bolts, or cut to fit inside of bolts, and shall be used on all flanged joints intended to be watertight.

25.2. Gasket material shall be either sheet asbestos, a rubber composition, or paper free from corrosive ingredients, either alkaline or acid.

Sec. 26—Workmanship

26.1. All workmanship employed in the fabrication and assembly of valves covered by this standard shall be first class in every respect. Valve parts shall be designed, and manufacturing tolerances set, to provide interchangeability in the products of any one manufacturer between units of the same size and type, except the individual fit of the wedge in the body. When assembled, valves manufactured in accordance with this standard shall be well fitted and smooth operating.

26.2. Unless spot-facing is required by supplementary specifications, the bolt holes of the end flanges shall not be spot-faced, except as specified in ASA B16.1.*

26.3. All castings shall be clean and sound, without defects that will impair their service. No plugging, welding, or repairing of such defects will be allowed.

Sec. 27—Painting

An asphalt varnish made to comply with Federal Specification TT-V-51a or Joint Army-Navy Specification JAN-P-450 shall be applied to the ferrous part of the valves, except finished or bearing surfaces. Surfaces shall be clean, dry, and free from grease before painting. Two coats shall be applied to both the inside and outside ferrous metal.

Sec. 28—Markings

28.1. *General.* Markings shall be cast on the bonnet or body of each valve and shall show the manufacturer's name or mark, the year the valve casting was made, the size of the valve, and the designation of working water pressure—150 W for 16–48-in. valves or 175 W for 3–12-in. valves (or higher if the valve is designed for a higher rated pressure). Special markings in addition to these can be supplied, when specified by supplementary requirements, upon agreement between purchaser and manufacturer.

28.2. *AWWA certification mark.* A manufacturer licensed to do so

---

* Introductory Note 12 of ASA B16.1 reads as follows:

Spot-Facing. Flanges. The bolt holes of these cast-iron flanges need not be spot-faced for ordinary service except as follows: in sizes 12 in. and smaller when rough flanges, after facing, are oversize more than $\frac{1}{8}$ in. in thickness, they shall be spot-faced to the specified thickness of flange (minimum) with a plus tolerance of $\frac{1}{16}$ in. In sizes 14 to 24 in., inclusive, when rough flanges, after facing, are oversize more than $\frac{1}{8}$ in. in thickness, they shall be spot-faced to the specified thickness of flange (minimum) with a plus tolerance of $\frac{1}{16}$ in. In sizes 30 in. and larger when rough flanges, after facing, are oversize more than $\frac{1}{4}$ in. in thickness, they shall be spot-faced to the specified thickness of flange (minimum) with a plus tolerance of $\frac{1}{8}$ in.

Spot-Facing. Fittings. The bolt holes of the flanges on these cast-iron fittings need not be spot-faced on sizes smaller than 18 in. for ordinary service, except as required for oversize thickness of flanges as indicated above. The bolt holes of all flanges on fittings 18 to 24 in., inclusive, shall be spot-faced to the specified thickness of the flange (minimum) with a plus tolerance of $\frac{1}{16}$ in. The bolt holes of all flanges on fittings 30 to 48 in., inclusive, shall be spot-faced to the specified thickness of the flange (minimum) with a plus tolerance of $\frac{1}{8}$ in.

Where spot-facing of flanges and fittings is necessary, the spot-facing diameter shall be in accordance with MSS Standard Practice SP-9-1947.

shall, subject to the provisions of the license, place on each valve made by him the registered certification mark of AWWA.

28.3. *Unauthorized reference to AWWA.* Except as provided in Sec. 28.2, no valve shall bear any mark in any way referring to this standard or to AWWA.

Sec. 29—Testing

29.1. *Performance tests.* After completion, each gate valve shall be tested at the shop for performance in operation, watertightness, and resistance to distortion under internal pressure which would cause leakage in excess of that specified in Sec. 29.2.

Each valve shall be operated in the position that it will assume in service and for the full length of gate travel in both directions, to insure the free and perfect functioning of all parts in the intended manner. Any defects of workmanship shall be corrected and the test repeated until satisfactory performance is demonstrated.

29.2. *Hydrostatic tests.* Each valve shall be subjected to hydrostatic test. For valves not rated above the figure specified in Sec. 2, the test pressures shall be as follows: for 3–12-in. valves, 175 and 300 psi; for 16–48-in. valves, 150 and 300 psi.* The tests shall be conducted in the following manner:

29.2.1. For double-disc gate valves, the 300-psi hydrostatic pressure * shall be applied between the discs; this test shall show no leakage through the metal or flange joints. Subsequently, a test shall be made at the rated pressure, applied between the discs; this second test shall show no leakage through the metal or flange joints, and the leakage past either seat shall not exceed a rate of 1 fl oz/hr per inch of nominal valve size.

29.2.2. For solid-wedge gate valves, the 300-psi hydrostatic pressure * shall be applied with both ends bulkheaded and the gate open; this test shall show no leakage through the metal or flange joints. Subsequently, a test shall be made at the rated pressure, applied (through bulkheads) alternately to each side of the closed gate with the opposite side open for inspection; this second test shall show no leakage through the metal or flange joints, and the leakage past either seat shall not exceed a rate of 1 fl oz/hr per inch of nominal valve size.

Sec. 30—Inspection and Rejection

30.1. *Purchaser's inspector.* All work under this standard shall be subject to inspection and approval by the purchaser's duly authorized engineer or inspector, who shall at all times have access to all places of manufacture where materials are being produced or fabricated or tests are being conducted, and who shall be accorded full facilities for inspection and observation of tests. Any gate valve or part which he may condemn as not conforming to the requirements of this standard shall be made satisfactory or shall be rejected and replaced.

30.2. *Manufacturer's warranty.* If the purchaser has no inspector at the plant, the manufacturer shall, if requested at the time the order is placed, certify that the required tests on the various materials and on the completed valve have been made, and that the results of all tests conform to the requirements of this standard.

* Valves rated above the figure specified in Sec. 2 shall be tested at the rated pressure and at twice the rating.

Sec. 31—Preparation for Shipment

31.1. Valves shall be complete in all details when shipped. The manufacturer shall use care in preparing them for shipment so that no damage due to the manufacturer's negligence will occur in handling or in transit. Valves must be drained and completely closed before shipment.

31.2. Valves 24 in. and larger in diameter shall be securely bolted or otherwise fastened to skids in such manner that they may be safely unloaded with a crane.

Notes

The valve illustrations (Fig. 1–3) point out some of the stipulations of this standard, but show also some variations in commercial design on which the purchaser may exercise a choice. The purchaser should state all his requirements at the time of purchase. No one manufacturer may be prepared to furnish valves in all applicable variations.

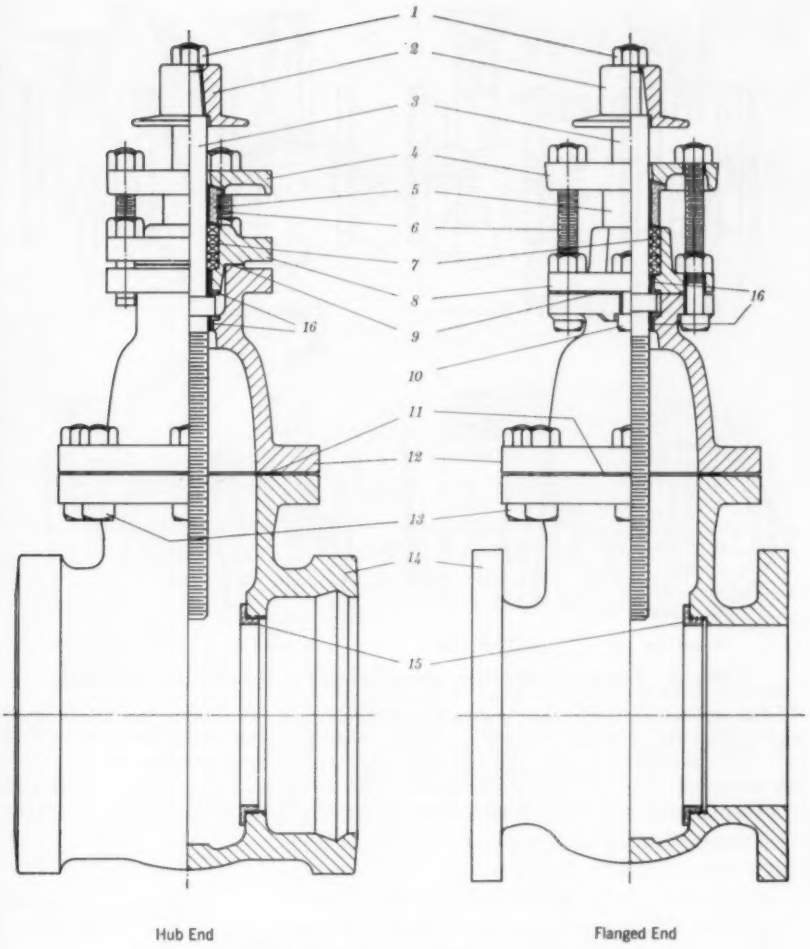


Fig. 1. Double-Disc Gate Valves With Nonrising Stems

The numbers on the figure refer to the following parts:

1—*Nut for wrench nut*
2—*Wrench nut*
3—*Stem*
4—*Gland flange (or follower)*
5—*Gland*
6—*Gland bolts and nuts*
7—*Stem packing*
8—*Stuffing box*
9—*Stuffing box gasket*
10—*Stuffing box bolts and nuts or studs and nuts*
11—*Bonnet gasket*
12—*Bonnet*
13—*Bolts, bolt-studs, and nuts for bonnet*
14—*Body*
15—*Seat ring (body)*
16—*Stem collar thrust bushing*

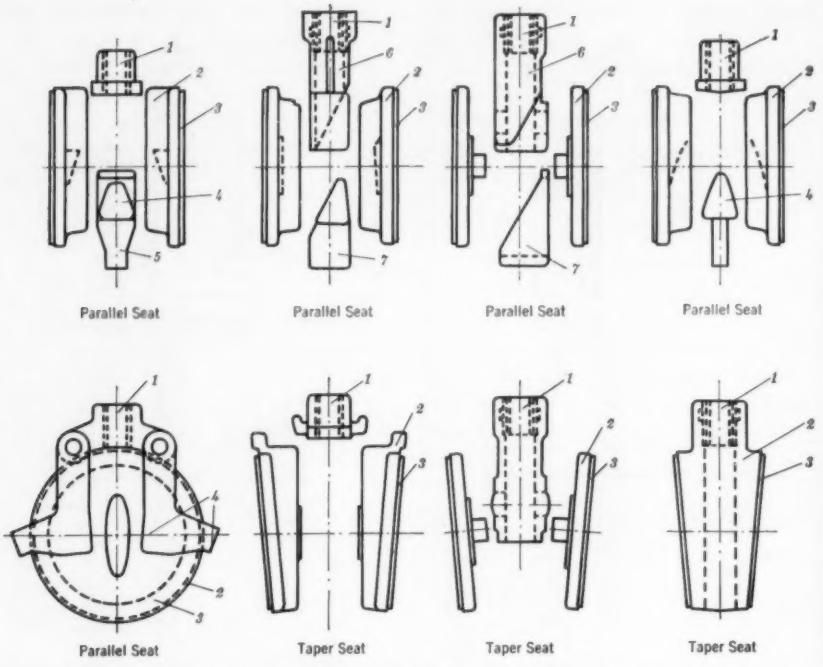


Fig. 2. Various Double-Disc Assemblies and a Solid-Wedge Assembly

All the figures illustrate double-disc assemblies except the lower right-hand figure, which illustrates a wedge assembly. Only typical principal elements are shown; details of wedge assembly and linkage must comply with requirements of Sec. 13.1 of this standard. The numbers on the figures refer to the following parts: [1] stem nut, [2] disc, [3] disc ring, [4] wedge, [5] wedge hook, [6] top wedge, [7] bottom wedge.

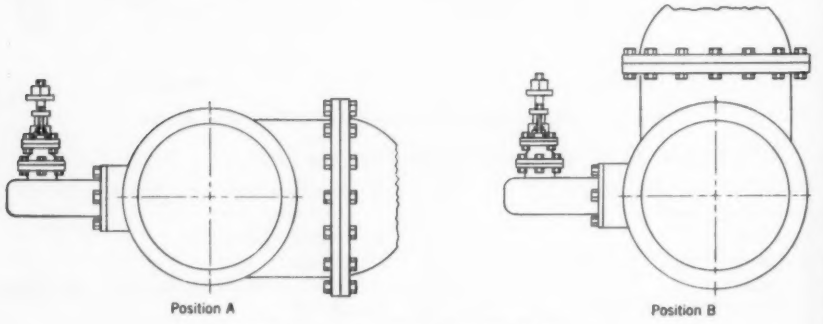


Fig. 3. Location of Bypass Valve

In Position A the main valve is installed horizontally, and in Position B it is installed vertically.

your best customers are the ones you never hear from!

AQUA NUCHAR

ACTIVATED CARBON FOR TASTE AND ODOR CONTROL

You keep customers happy and complaints at a minimum when you eliminate taste and odor problems with daily threshold odor tests and adequate dosages of AQUA NUCHAR Activated Carbon.

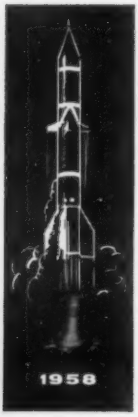
AQUA NUCHAR's unique surface adsorbs tastes and odors from algae, decaying vegetation, trade wastes and other matter . . . leaves "sweet", sparkling water with perfect, consistent PALATABILITY. Concentrations required average as low as 2–5 ppm. AQUA NUCHAR is economical, too.

Our field technical service staff will be happy to assist you in setting up a PALATABILITY program in your plant. Call or write us today

industrial
CHEMICAL SALES
division west virginia pulp and paper company

230 Park Ave., New York 17 · Philadelphia National Bank Bldg., Philadelphia 7
35 E. Wacker Dr., Chicago 1 · 2775 S. Moreland Blvd., Cleveland 20

The meter you buy today...



will it meet *1988* standards?

When buying new water meters, a most important question of cost is: "In 30 years will this meter be *scrapped*, or will it be rebuilt to *1988* standards at a fraction of the cost . . . ready for years more accurate service?"

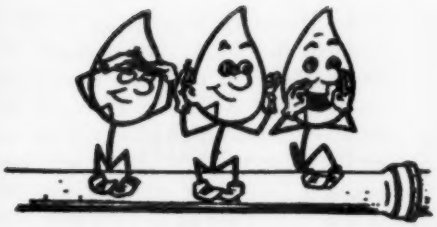
Take a look at the *past* 30 years. Think how much you're saving *this* year on Trident meters installed back in 1928 . . . or even 30 years before that.

Under Trident's strict policy of interchangeability, all improved parts are designed to fit old Tridents too. These up-to-date Trident parts embody every thoroughly tested advancement known to metering science. Not only is repairing easy and economical, but also you actually modernize your Tridents as you go.

This has been a rigid Neptune policy for 60 years. *Every design improvement now on our drawing boards will continue it.* It's your best assurance that the Tridents you buy today will stay modern, earning maximum revenue for your water system . . . at lowest cost . . . for many years to come.

NEPTUNE METER COMPANY
19 West 50th Street • New York 20, N. Y.
NEPTUNE METERS, LTD.
1430 Lakeshore Road • Toronto 14, Ontario
Branch Offices in Principal American and Canadian Cities.

neptune
TRIDENT/WATER METERS



Percolation and Runoff

San Francisco is the place, this is the time, and described below are the officers and directors taking office at what seemed when this was written to have been by the time you read it the biggest meeting in AWWA history:

President—Lauren W. Grayson, general manager and chief engineer, Public Service Dept., Glendale, Calif. Born in Boone, Iowa, in 1907, he joined the staff of the Riverside, Calif., Dept. of Public Utilities in 1926 and was appointed general manager in 1942. In 1951 he accepted the position of general manager and chief engineer with the Public Service Dept. of Glendale, Calif. He is a registered professional engineer in that state.

An AWWA member since 1933, he has served the California Section as vice-chairman (1948), chairman (1949), and national director (1952–54). In 1947 he was director of the former AWWA Plant Management and Operation Division, and was successively trustee (1948), vice-chairman (1955), and chairman (1956) of the Water Works Management Division, as well as vice-chairman (1948) and chairman (1949) of the Water Resources Division. He was AWWA vice-president in 1958–59.

Other professional organizations to which he belongs include ASCE and the California Municipal Utilities Assn. (president).

Vice-President—C. F. Wertz, director, Dept. of Water & Sewers, Miami, Fla. Born in Reading, Pa., in 1898, he received a B.S. in sanitary engineering from Pennsylvania State College in 1920, after which he began his professional career as assistant engineer with the State Board of Health. From 1926 to 1941 he held assignments with various engineering firms in New York, Pennsylvania, and Ohio. In 1941 the firm of Day & Zimmermann, Inc., of Philadelphia, sent him to Miami on a property management assignment for the city's Dept. of Water & Sewers. He served in that capacity until 1955, when he obtained his present position as department director. He is a registered professional engineer in Pennsylvania and Florida.

A Life Member of AWWA (joined in 1924), he served the Florida Section as vice-chairman (1946), chairman (1947), and national director (1951–54). The section nominated him for the Fuller Award in 1947. He has been a member of the Water Works

(Continued on page 38 P&R)

(Continued from page 37 P&R)

V.P.—Wertz

Treas.—Orchard

Practice Committee, the Committee on Joint Administration of Water and Sewer Facilities, and the Committee on Procedure for Disinfecting Water Mains. In 1951 he was chairman of the Convention Management Committee.

Other technical societies to which he belongs are ASCE, FSIWA, Florida Sewage Works Assn., Pennsylvania Sewage & Industrial Wastes Assn., and Pennsylvania Water Works Operators Assn.

Treasurer—William J. Orchard, consultant, Wallace & Tiernan Inc., Belleville, N.J. Born in Boston, Mass., in 1888, he was graduated from Massachusetts Institute of Technology in 1911 with a degree in sanitary engineering. He served with the Massachusetts Board of Health and the Metropolitan Water Commission, and also held the post of assistant sanitary engineer with the New Jersey Health Dept. In 1915 he entered the employ of the Wallace & Tiernan organization. During World War I he originated and developed mobile water purification equipment for the US Army. He rose to the position of general manager of Wallace & Tiernan, retiring in 1954 but continuing as consultant to the company.

An Honorary Member of AWWA (joined in 1917), he received the Diven Medal in 1954 and the Jordan Achievement Award in 1956. A director for many years, he has served as chairman of the Convention Management Committee and as a member of the Executive Committee and the General Policy Committee. He was chairman of the Finance Committee from 1951 to 1957, when he was elected treasurer. Other organizations to which he belongs include WSWMA (past president), NEWWA, FSIWA, and APHA.

SECTION DIRECTORS

Alabama-Mississippi—Jess L. Haley, superintendent, Public Utilities Commission, Clarksdale, Miss. Born in Itta Bena, Miss., in 1913, he received a B.S. in electrical engineering from Mississippi State University in 1935. Prior to accepting his present position, he served with the Memphis (Tenn.) Light, Gas & Water Div. and with the city of Amory, Miss.

A member of AWWA since 1947, he has served his section as vice-chairman (1954) and chairman (1955), and was nominated for the Fuller Award in 1957. He is a member of American

Ala.-Miss.—Haley

Ariz.—Gardner

(Continued on page 40 P&R)

EMINENCE IN EQUIPMENT DESIGN · INFILCO · GIVES YOU PLUS VALUES ·

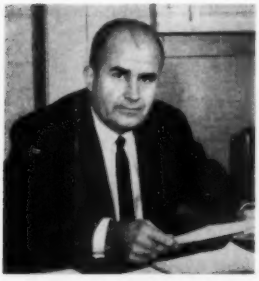
NOW... INFILCO RESEARCH and DEVELOPMENT DIVISION EXPANDED

to give you more PLUS VALUES than ever

Recommendations are based on analyses and laboratory tests.

Precision components are thoroughly tested and calibrated.

Equipment is custom designed for your specific requirements.



A. A. Kalinske, Vice President in charge of Research and Development.

Continuous improvements in equipment and methods for

- water softening and clarification
- sewage treatment
- pollution abatement
- valuable material recovery

...these have been the objectives of INFILCO for many years. The Research and Development Division has been expanded to accelerate new developments in water and waste treatment – and to work with you and your engineer for the solution of specific problems.

INFILCO INC.
General Offices
Tucson, Arizona

Field offices throughout the United States and other countries

INFILCO

(Continued from page 38 P&R)

Public Power Assn. and National Society of Professional Engineers, and is a registered engineer in Mississippi and Tennessee.

Arizona—Leigh O. Gardner, partner, Yost & Gardner Engineers, Phoenix, Ariz. Born in Safford, Ariz., in 1912, he received his B.S. in civil engineering from the University of Arizona in 1933. After filling various government and private engineering assignments, he entered his present partnership in 1943. Other professional affiliations include: ASCE (section president), FSIWA (director), and Arizona Council of Engineering & Scientific Assns. (president). He has been an AWWA member since 1942.

Kentucky-Tennessee—Justin J. Davis, director, Water Div., Memphis (Tenn.) Light, Gas & Water Div. Born in Chicago in 1898, he attended Christian Brothers College. In 1921 he joined the Memphis Artesian Water Co. (which later became the present division) as junior engineer and draftsman. From 1942 to 1956 he served both as chief engineer of the Water Engineering Dept. and as assistant to the director of the Water Div. He was appointed to his present position in 1956.

Ky.-Tenn.—Davis

Mich.—Self

Nebraska—Beard

New England—Kennison

A corporate representative in AWWA since 1949, he has served as trustee (1953–55) and chairman (1956) of the Kentucky-Tennessee Section.

Michigan—Herschel O. Self, superintendent of water supply and sewage disposal, Flint, Mich. Born in Greenfield, Tenn., in 1898, he studied business administration at Marvin College, graduating in 1916. He has been associated with the city of Flint since 1919, starting with the Div. of Water Supply as customer man. After serving as accounting and office supervisor (1925–47) and office and distribution supervisor (1947–50), he obtained his present position in 1950.

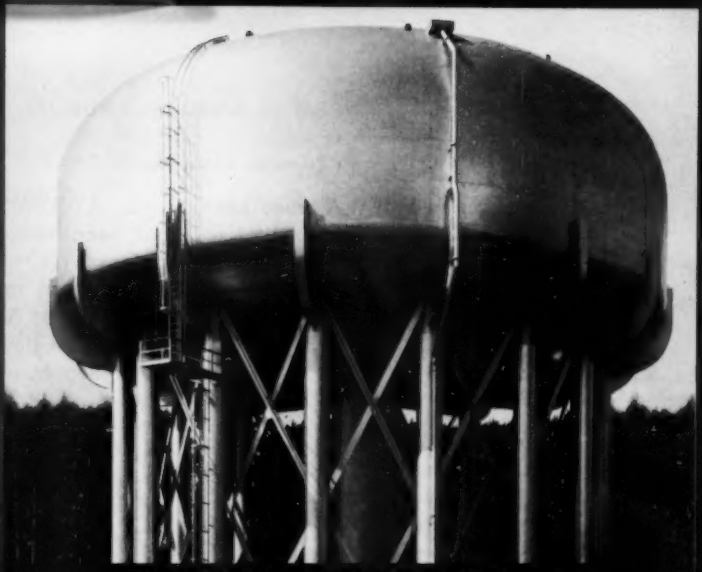
A corporate representative in or active member of AWWA since 1938, he has served the Michigan Section as vice-chairman (1954) and chairman (1955). He is also a member of the water committee of the Michigan Natural Resources Council.

Nebraska—George H. Beard, vice-president and branch manager, Layne-Western Co., Omaha, Neb. Born in Farmington, Mo., in 1908, he received his B.S. in electrical engineering from the University of Missouri in 1931. He is a registered professional engineer in Nebraska and Iowa.

(Continued on page 42 P&R)

PDM
ELEVATED STEEL TANKS

ELEVATED STEEL TANKS



Radial cone tank, Seattle, Wash. Capacity 2,000,000 gallons.

FIRST IN EXCELLENCE

TO SERVE DEPENDABLY THE WATER STORAGE NEEDS OF MODERN AMERICAN COMMUNITIES

Pittsburgh-Des Moines

From the first PDM Elevated Steel Tank, pioneered in 1897, to the handsome structures of the present, *first quality* has been our continually-realized objective. You'll find in the wide range of PDM tank types and capacities the ideal unit for your requirements—guaranteed in performance and satisfaction. Let us submit a quotation.

Toro-segmental tank, Sioux City, Ia. acity 2,000,000 gallons.

Radial cone tank, Independence, Kansas. Capacity 750,000 gallons.

Double-ellipsoidal tank, Melbourne, Fla. Capacity 300,000 gallons.

Pedestal sphere, Hawthorne, Calif. Capacity 250,000 gallons.

RITE FOR this fully-ustrated 28-page lodern Water Storage" ochure—detailing the ge of PDM Elevated el Tanks. Free on re-est to our nearest ice.

Pittsburgh-Des Moines Steel Company

Plants at PITTSBURGH, BALTIMORE, DES MOINES, SANTA CLARA, FRESNO, and STOCKTON, CALIF.

Sales Offices at:

PITTSBURGH (25).....3424 Neville Island
BALTIMORE (26).....Curtis Bay Station
NEW YORK (17).Suite 2721, 200 E. 42nd St.
CHICAGO (3), 628 First National Bank Bldg.
EL MONTE, CAL.....P. O. Box 2012
ATLANTA (5)..361 E. Paces Ferry Rd., N.E.
DES MOINES (8).....925 Tuttle Street
DALLAS (1).....1229 Praetorian Bldg.
SEATTLE (1).....Suite 332, 500 Wall St.
SANTA CLARA, CAL.....631 Alviso Road
DENVER (2)...323 Railway Exchange Bldg.

(Continued from page 40 P&R)

A member of AWWA since 1945, he has served as chairman of the Nebraska Section (1957). Other professional affiliations include: National Society of Professional Engineers (state director), Society of American Military Engineers, and Nebraska Engineering Society.

New England—Karl R. Kennison, consulting engineer, Norwalk, Conn. Born in Marysville, N.B., in 1886, he received his A.B. from Colby College in 1906 and his B.S. from Massachusetts Institute of Technology in 1908. An AWWA member since 1939, he received the Fuller Award in 1951.

N.J.—Bonyun

N.Y.—Diven

Other technical societies of which he is a member include NEWWA (president), ASCE (section president), Boston Society of Civil Engineers (president), and New England Sewage & Industrial Wastes Assn.

New Jersey—Richard E. Bonyun, general superintendent and chief engineer, Passaic Valley Water Commission, Clifton, N.J. Born in Atlanta, Ga., in 1901, he graduated from Cornell University in 1925 with a degree in civil engineering. He has been with the Passaic Valley organization since 1933.

An AWWA member since 1935, he has been vice-chairman (1949) and chairman (1950) of the New Jersey Section, and in 1952 was nominated for the Fuller Award. He is currently chairman of the section's committee on water supply. Other technical societies of which he is a member are ASCE, New Jersey Sewage & Industrial Wastes Assn., and the state's Water Policy & Supply Council.

New York—John M. Diven, manufacturer's representative, Jackson Heights, N.Y. Born in Elmira, N.Y., he received his degree in civil engineering from Rensselaer Polytechnic Institute. His experience has included utility operation, construction engineering, and engineering service with the US Army (Chemical Corps).

A Life Member of AWWA (joined in 1913), he has been vice-chairman (1957) and chairman (1958) of the New York Section. In 1948 he was nominated by the section for the Fuller Award. Other professional affiliations include ASCE and NEWWA. He is a son of former AWWA President and Secretary John M. Diven, in whose memory an annual award for outstanding service was established in 1925.

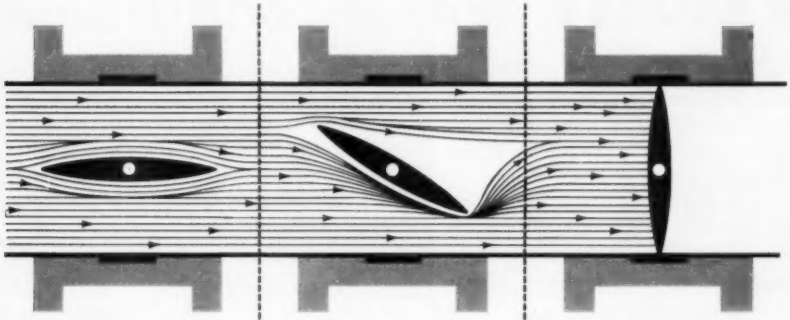
Pacific Northwest—Winston H. Berkeley, assistant water operations superintendent, Eugene (Ore.) Water & Electric Board. Born in Clear Lake, Iowa, in 1900, he served for 15 years as filter plant superintendent at Lewiston, Idaho, before assuming the same position at Eugene in 1953. He was named assistant superintendent in 1956. An AWWA member since 1939, he was chairman of the Pacific Northwest

(Continued on page 46 P&R)

BUTTERFLY VALVE FACT FILE

3 jobs a valve should do

The three functions of a valve are these ...
1... to provide free flow when open,
2... to control flow in intermediate positions,
3... to shut off completely when closed.
Not all valves can do *all* these tasks with equal efficiency, and in many cases, the installation of two valves in series has become an expensive and awkward compromise. Let's see how butterfly valves (as built by Henry Pratt) meet the three vital essentials:



FREE FLOW WHEN OPEN
A lens shaped, streamlined valve disc offers the least possible resistance to flow. Actual head loss factor (K) in a fully opened low pressure valve is equal to 0.263, or only 60% of the loss through a 45° pipe elbow.

EFFECTIVE FLOW CONTROL
Flow characteristics of a butterfly valve are similar to those of a V-port plug valve, but with only ⅓ the head loss in the open position. Butterfly valves have a minimum to maximum controllable flow ratio (rangeability) of 25 to 1.

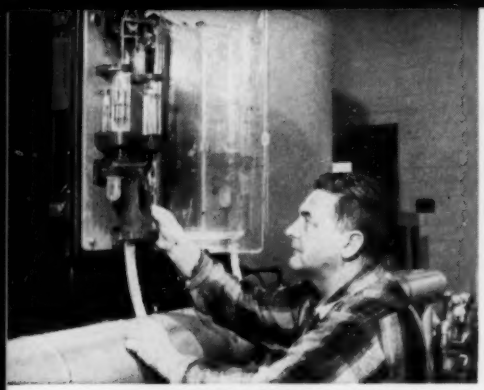
TIGHT CLOSURE
Closing smoothly into the seat, the disc squeezes into the rubber to obtain closure. Heavy rubber seat minimizes wear, assuring **continued** tight shutoff; corrosion resistant disc edge means valve will operate easily even after being closed for years.

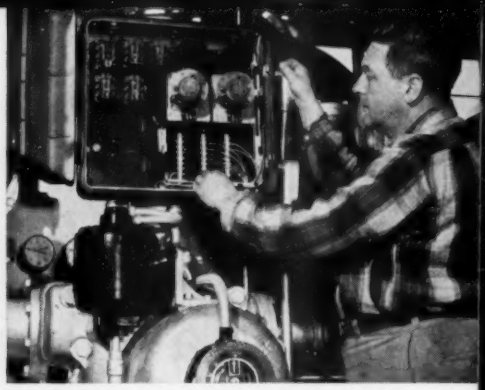
See us in booths 59–61 at the AWWA Convention in San Francisco.

HENRY PRATT — RUBBER SEAT Butterfly Valves

If you would like more technical data on butterfly valves, write for the Henry Pratt Manual of Rubber Seat Butterfly Valves B-2C.

HENRY PRATT COMPANY, 2222 S. HALSTED ST., CHICAGO 8, ILL. • REPRESENTATIVES IN PRINCIPAL CITIES





HARDNESS TESTER (left) initiates regeneration by Automatic Controls (right). This new Permutit plant, with Q resin, softens 72% more water—using same manpower, less salt! E. Aurora, N. Y. Village Eng.: *E. J. Maurer.*

Why these cities chose PERMUTIT® *water conditioning*

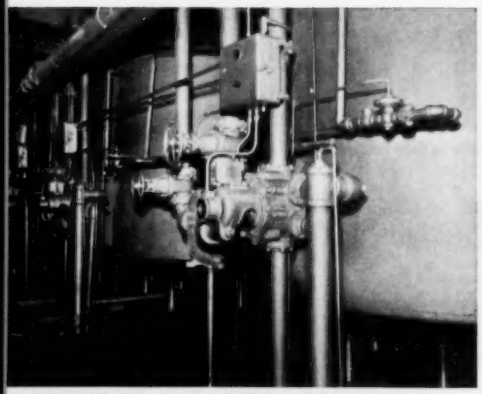
Some chose Permutit for its world-known engineering experience gained through thousands of installations covering every major development in clarification, filtration and softening equipment.

Others chose Permutit to get complete, integrated service: the water-analysis labs, engineering, equipment, controls, ion exchange resins—all from one source, under one responsibility.

But most of the designers of these plants chose Permutit because they have personal knowledge of many installations where Permutit equipment has given long years of efficient, trouble-free performance. They know that's what pays off in the long run.

The Permutit Company, Dept. JA-79, 50 West 44th St., New York 36, N. Y. (a division of Pfaudler Permutit Inc.)

SOFTENERS • ZEOLITES and RESINS • AUTOMATIC CONTROLS • GRAVITY FILTERS • PRESSURE FILTERS
PRECIPITATORS • CHEMICAL FEEDERS • AERATORS • SWIMMING POOL SYSTEMS • IRON REMOVAL EQUIPMENT

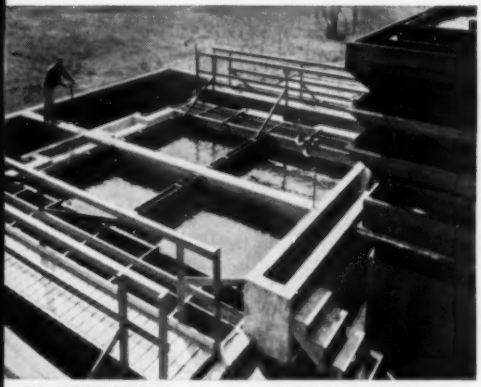


SOFTENER CAPACITY TRIPLED and $7,000 yearly saved on salt by change from zeolite to Permutit Q. Normal, Ill. Cons. Eng.: *Farnsworth & Conley.*

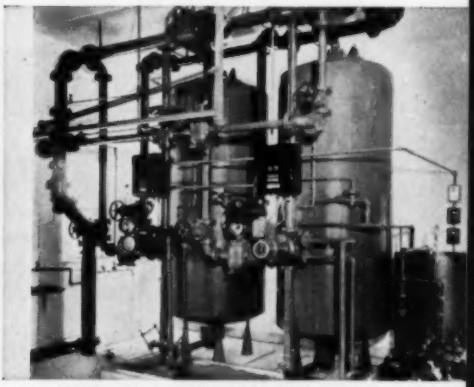
TRIPLE TROUBLE! 275 ppm hardness, 200 ppm alkalinity, 3 ppm iron are reduced by this Precipitator. Staples, Minnesota. Supt.: *E. H. Klang.*

TURBIDITY gets cut from 1500 to less than 5 ppm in this Precipitator. Mt. Carmel, Ill. Cons. Eng.: *Warren & Van Praag, Inc.*

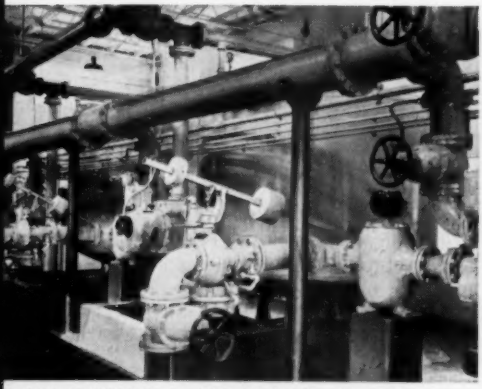
SEA WATER saves $32,980 per year over salt for regenerating Softeners. Hollywood, Fla. Cons. Eng.: *Reynolds, Smith & Hills.*



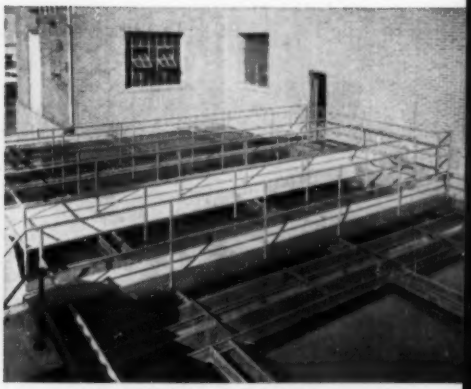
30 PPM IRON gets cut to 0.14 ppm in Aerator and Precipitator . . . even before filtration! Fairless Hills, Pa. Cons. Eng.: *H. H. Le Van, Jr.*



269 PPM HARDNESS is removed by these automatic Softeners. Aerator and Filters cut iron. Martinsville, Ill. Supt.: *O. Wiser.*



AUTOMATIC CONTROLS backwash, regenerate, rinse and return Softeners to service. New Smyrna Beach, Fla. Cons. Eng.: *Russell & Axon.*



OLD SETTLING BASINS house these modern Precipitators that boost capacity. North Kansas City, Mo. Cons. Eng.: *C. A. Haskins.*

(Continued from page 42 P&R)

Section in 1954 and received the Fuller Award in 1951.

Pennsylvania—Samuel S. Baxter, commissioner and chief engineer, Philadelphia Water Dept. Born in Philadelphia in 1905, he graduated from Drexel Institute of Technology in 1925. He has been with the city's Dept. of Public Works since 1923, when he joined the engineering staff. He became division engineer in 1932, assistant director in 1940, assistant chief engineer in 1947, and chief engineer in 1950, and was named to his present position in 1952.

A member of AWWA since 1952, he has served as a member of the Pennsylvania Section's executive committee since 1957. Other professional affiliations include: ASCE, American Public Works Assn. (president), American Society of Public Administration, FSIWA, and Pennsylvania Society of Professional Engineers.

Manufacturer—Richard V. Ford, vice-president and export manager, Ford Meter Box Co., Haddonfield, N.J. Born in Hartford City, Ind., in 1900, he received his B.S. in chemical engineering from Purdue University in 1922, after which he joined the Worthington Corp. Since 1928 he has been with his present firm.

Mfrer.—Ford

A member of AWWA since 1942, he is currently secretary of the Task Group on Review and Redevelopment of a Rating Scale for Water Works. In 1958 he was president of WSWMA. He is also a member of Inter-American Assn. of Sanitary Engineers and Maryland-Delaware Water & Sewage Assn.

Pacific Northwest —Berkeley

Pennsylvania— Baxter

'All the Water You Need, When and Where You Need It'—the promise to the public that we have long urged upon water utilities—seems suddenly to have gained currency on even a grander scale than we proposed. Just how grand may best be suggested by the 2,000,000 "grand" estimated cost of a California plan for which Governor Brown has proposed that the state—rather than the federal government—accept prime responsibility as a means of "seeing that everyone is supplied with the water he needs when he needs it." And the good news from that water front is that North and South are finally looking for a solution rather than for more ammunition in their dispute over the use of northern water for southern development. In New Jersey, meanwhile, the agreement be-

(Continued on page 48 P&R)

In our new plant (shown below)

HERSEY WATER METERS

are made by the most modern techniques and machines, from the automatic bronze foundry to the final test lines producing up to 7000 GPM of water.

Here is made the most complete line of Water Meters for every purpose.

HERSEY MANUFACTURING COMPANY

(Established 1859)

DEDHAM, MASS.

BRANCH OFFICES: NEW YORK — PORTLAND, ORE. — PHILADELPHIA — ATLANTA — DALLAS — CHICAGO
SAN FRANCISCO — LOS ANGELES

"You can't buy a better Water Meter than HERSEY."

APCO
Super
De Lavaud
CAST IRON
PIPE
In sizes 3" to 24" in modern long lengths. Bell and spigot, roll-on-joint and mechanical joint.
For water, gas and sewage.
For The Best Connection You'll Ever Make Investigate The New ALTITE JOINT ® by APCO
Underwriters Approved
Patent Applied For.
ALABAMA PIPE COMPANY
General Offices—
ANNISTON, ALABAMA
SALES OFFICES
122 South Michigan Ave., Chicago 3, Ill.
350 Fifth Ave., New York 1, N. Y.
950 Dirks Building, Kansas City, Mo.
18505 W. Eight Mile Rd., Detroit 41, Mich.
5335 Southern Ave., South Gate, Calif.
APCO CAST IRON SUPER DE LAVAUD

(Continued from page 46 P&R)

tween North and South that last year cleared the way for state construction of two long needed reservoirs promises a less contentious future for those who see "all the water they need" as the only means of holding the state's present industries, not to mention attracting new ones. Elsewhere in the New York metropolitan area, efforts to guarantee "all the water a booming population needs" are of first interest. New York City is already planning a 120-in. water tunnel under the bay to Staten Island to satisfy the greatly increased requirements of that borough which are sure to follow completion of the new bridge connecting it with Brooklyn. Nassau County on Long Island recently offered New York City $5,000,000 for now abandoned water properties and easements to counteract county water deficiencies expected by the year 2000. And Westchester County has been working just as far ahead in some of the projects being promoted by its County Water Agency. With other parts of the nation equally concerned, even Congress has taken cognizance of the importance of water supply in the formation of the Senate Select Committee on National Water Resources with a 1959 budget of $175,000 to conduct a "vigorous, forward-looking review of the nation's water needs."

As if to attest to the proximity of the millennium, a headline in the Philadelphia *Evening Bulletin* for May 10 reads: "USE MORE WATER, CITY BEGS, AS IT READIES NEW PLANT." And the story lived up to the headline, reporting Water Commissioner Sam Baxter's plans to launch an advertising campaign to sell the product of the city's new $25,000,000 treatment plant at Torresdale. Point-

(Continued on page 50 P&R)

The New York City Croton Watershed encompasses portions of three counties in New York State and one county in Connecticut.

Fairchild Aerial Surveys, Inc.

How New York City is guarding its Croton Watershed against pollution

Migration to suburbia is creating a potential pollution problem of one of New York City's major watersheds. Here is what they are doing about it.

To meet the problem headon, the New York City Department of Water Supply, Gas and Electricity, under the direction of Commissioner Armand D'Angelo and Chief Engineer Edward J. Clark, has initiated a comprehensive sanitary survey. The New York City Croton and Kensico Watersheds cover a total of 400 square miles. A tremendous building boom in the watershed areas has brought with it a progressive and wide-spread problem of sewage and industrial wastes disposal. If the threat of pollution were ignored, New York City Engineers say that the usefulness of the watersheds would be seriously impaired.

Realizing that complete information on the watershed areas is needed before intelligent planning can be done, the Department's engineers working with representatives of Fairchild Aerial Surveys, Inc., prepared a program of aerial mapping of the complete area. Contact prints at a scale of 1" = 2000' and individual enlargements at a scale of 1" = 400' have already been delivered. Topographic maps, which include all cultural and physical features of the area, and soil analysis maps have been ordered and will soon be completed.

Once the Water Supply Engineers have the topographic and soils information, they will be able to plan and coordinate the construction of essential sanitary facilities in the watersheds. In addition, in areas of critical importance these maps will enable engineers to design sewerage systems for carrying the waste products off the watersheds.

Most cities today have planning problems. Fairchild aerial photomaps and topographic maps have proved to be valuable aids in making intelligent city planning decisions. Call your nearest Fairchild office and have the many Fairchild services explained to you.

FAIRCHILD
AERIAL SURVEYS, INC.

Los Angeles, California: 224 East Eleventh Street • New York City, New York: 9 Rockefeller Plaza • Chicago, Illinois: 111 West Washington Street • Boston, Massachusetts: New England Survey Service, 255 Atlantic Avenue • Birmingham, Alabama: 2229 First Avenue North • Houston, Texas: 3325 Las Palmas

(Continued from page 48 P&R)

ing out that the new plant supplying approximately half the city will have a capacity of 423 mgd, compared with the 200 mgd of the one it replaces, Sam noted that "in advertising and merchandising its product the Water Department is doing nothing more than following the good business practices followed by such other utilities as the electric, gas, and telephone companies." Than which, who could ask for anything more?

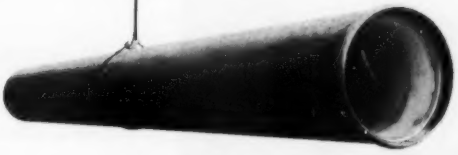
The BDSA Executive Reserve met in Washington, D.C., in May for a briefing on defense mobilization plans, conducted by a number of prominent government officials, including Commerce Secretary Lewis L. Strauss, CIA Director Allen W. Dulles, Assistant Commerce Secretary Carl F. Oechsle, and BDSA Administrator Horace B. McCoy—the last two being pictured above with Walter L. Picton, director of the Water & Sewerage Industry & Utilities Div. of BDSA, and 25 of the division's reservists. Seated from left to right are: H. W. Hitzrot, D. L. Muss, R. H. Lancaster, G. P. Gabosch, W. L. Picton, R. E. Hebert, L. L. Smith, A. B. Kaltenbach, J. C. Crenshaw, C. W. Wilson, and H. S. Howe. Standing are: X. D. Murden, G. A. Shaffer, C. H. Bagwell, W. M. Franklin, M. C. Hagar, O. E. Walker, Leo Louis, H. B. McCoy, R. H. Ritter, C. F. Oechsle, H. A. White, C. F. Wertz, J. B. Cook, W. R. LaDue, H. F. Bower, R. V. Ford, and H. F. Seidel.

Hot ice has been distributed throughout Gainesville, Ga., for the past 3 years and it wasn't until last month that it was recognized as stolen water in disguise. Actually it was a tip from one of the icemen that brought city investigators to the Best Ice Co. with search warrants and led them to exhume from beneath a concrete floor an illegal connection to the city system

(Continued on page 52 P&R)

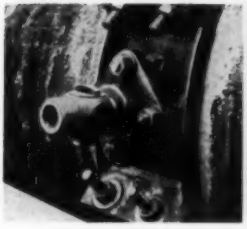
Tapping Water Lines Under Pressure

American Concrete Cylinder Pipe can be tapped with ease and economy while still under pressure.



The sudden explosive growth of many communities in the west has made it difficult for the best of advance planners to achieve both economy and adequate service in water supply systems designed for the future.

The possibility of unpredictable requirements for service outlets was one of the factors taken into consideration in the design of American Concrete Cylinder Pipe. Without de-watering the pipeline, small or large diameter outlets can be easily installed by any water works service group using standard tapping equipment. New outlying areas which mushroom in the typical western growth pattern can be readily integrated into a planned System if American Concrete Cylinder Pipe is used for the transmission lines.



CONCRETE PIPE FOR MAIN WATER SUPPLY LINES, STORM AND SANITARY SEWERS, SUBAQUEOUS LINES

American PIPE AND CONSTRUCTION CO.

LOS ANGELES: 4635 Firestone Blvd., South Gate, Calif.—LOrain 4-2511
HAYWARD: P. O. Box 630 — JEfferson 7-2072
SAN DIEGO: P. O. Box 13 — CYpress 6-6166
PORTLAND: 518 N. E. Columbia Blvd.— BUtler 5-2531
ALBUQUERQUE: P. O. Box 1782 — CHapel 7-0486
PHOENIX: American Concrete Pipe Co. (Subsidiary)
P.O. Box 12127 — Alpine 2-7566

(*Continued from page 50 P&R*)

through which the company had apparently drawn $200,000 worth of free water. Having four wells of its own, the company paid the water department a fee of $20 per month for fire sprinkler service, but drew no other water from the system—no other, that is, except the estimated 330 mil gal that it had pumped through the hidden connection from March 1956 on. In hot *water* now is J. P. Reynolds, president of the company, whom the county grand jury has charged with 27 counts of larceny, and if the charges are proved he will undoubtedly be on ice for some time unless he iced the income from some of the water sold to three nearby poultry concerns, which now pay the city monthly bills ranging from $800 to $2,000. Such an ice man he seemed, too!

Karl J. Fuss (right), water superintendent at Mattoon, Ill., hands Illinois Senator Paul Douglas the American Cancer Society's symbolic sword of hope at the society's Cured Cancer Congress in Washington, D.C. Superintendent Fuss, who was cured of cancer, attended the meeting as Illinois delegate.

On the engineering front EJC, ECPD, and NSPE have all been busy trying to obtain for the profession more face as well as more hands.

EJC had its president and vice-president before Senator Humphrey's subcommittee in April to urge the creation of a Cabinet-level Department of Science and—not Technology, but—Engineering "basically at the administrative level, the better to serve our national economy and our national defense." The EJC officers emphasized, however, that "science and engineering directly pertinent to the missions of certain departments must continue to be carried out within those departments" and offered the services of a special advisory committee to work with Congress "in any appropriate way."

EJC, through the chairman of its Engineering Manpower Commission, and ECPD, through its president, are helping to support the young Junior Engineering Technical Society by serving on its newly constituted board of directors. Founded at Michigan State University in 1950, the JETS now has more than 350 chapters across the country, aimed at stimulating interest in science and engineering among high school students, appraising their abilities, and leading qualified students into the profession.

EJC, together with the American Society for Engineering Education, has just published a study of "Salaries and Income of Engineering Teachers, 1958," authored for them by William H. Miernyk, director of the Bureau of Business & Economic Research at Northeastern University, Boston. In the booklet, which is obtainable from EJC at 25 cents per copy, a compari-

(*Continued on page 54 P&R*)

here's what "out of sight out of mind" does to a water main

"Out of sight—out of mind" can be a mighty expensive philosophy in any water distribution system. The above unretouched photograph proves this point. It shows a badly tuberculated *eight inch* main whose *inside diameter was reduced to an average of almost 4.5 inches.* Resultant higher pumping costs with reduced pressure and carrying capacity make it costly to tolerate such conditions. That is why the savings effected in reduced pumping costs frequently pay for the *low cost* of National water main cleaning.

Since there's never a charge or obligation to inspect your mains, *call National now!*

Call in National today!

NATIONAL WATER MAIN CLEANING COMPANY

50 Church Street • New York, N. Y.

333 Candler Building, Atlanta 3, Georgia; 920 Grayson St., Berkeley, Calif.; 115 Peterboro St., Boston 15, Mass.; 533 Hollis Road, Charlotte, N. C.; 8 S. Dearborn St., Rm. 808, Chicago 3, Ill.; P. O. Box 385, Decatur, Ga.; 2024 Merced Ave., El Monte, Calif.; 315 N. Crescent St., Flandreau, South Dakota; 3707 Madison Ave., Kansas City, Missouri; 200 Lumber Exchange Bldg., Minneapolis 1, Minn.; 510 Standard Oil Bldg., Omaha 2, Nebraska; 2910 W. Clay Street, Richmond 21, Va.; 502 West 3rd South, Salt Lake City 10, Utah; 204 Slayton St., Signal Mountain, Tenn., 424 S. Yale Avenue, Villa Park, Illinois; 7445 Chester Avenue, Montreal, Canada; 576 Wall Street, Winnipeg, Manitoba, Canada; Apartado de Correos No. 5, Bogota, Colombia; Apartado 561, Caracas, Venezuela; P. O. Box 531, Havana, Cuba; Marquinaria, Apartado 2184, San Juan 10, Puerto Rico; Bolivar 441-A, Marafl., Lima, Peru

(Continued from page 52 P&R)

son is made between 1956 and 1958 income, with breakdowns by type of institution, location, and rank in the profession.

EJC, through its Engineering Manpower Commission, again in conjunction with the American Society for Engineering Education, has just completed a study of the causes contributing to the drop of 11.1 per cent in freshman engineering enrollment in the fall of 1958, based on opinions of deans of engineering at 161 institutions. Primary causes involved were: a drop in applications from qualified students because of the news of extensive engineering layoffs during the recession, increased concern about the rigors of the engineering curriculum, and increased interest in other scientific fields; a drop in the percentage of applicants qualified either because of poorer applicants or higher admission standards; and an increase in the number of accepted applicants who did not enroll, resulting from the increase in the practice of multiple applications.

ECPD, as part of its Training Committee's "First Five Years" program, issued three new brochures to help guide young engineers. *Your First Five Years,* outlines a six-point professional-development program consisting of orientation and training in practice, continuing education, professional identification, responsible citizenship, selected reading, and personal appraisal. *Selected Reading for Young Engineers* contains a recommended reading list covering the fields of biography, travel, history, economics and sociology, psychology, philosophy, natural sciences, and general literature. *Personal Appraisal* presents a self-analysis questionnaire which identified the numerous professional standards to which a young engineer must adhere. The brochures are available from ECPD at 10, 15, and 10 cents respectively.

NSPE, in recommendations submitted to the chairmen of congressional appropriations committees, has urged that the maximum rate for temporary consultants engaged by the federal government be increased to $100 a day, pointing out that fees below this may very well deprive the federal government of the best qualified engineering talent.

NSPE, in its "Engineering Employment Practices Newsletter" for May, points out that officials of Canadian professional engineering associations have become concerned over large-scale advertising by US companies for engineers, when the companies advertising may actually be laying off engineers. The officials feel that the technique may

(Continued on page 100 P&R)

MONTEREY SAND CO.

Crystal Amber Filter Sand & Gravel

"The Standard of the Industry"

In conformity with A.W.W.A. specifications for filtering material or made to your own specification.

Shipped Bulk or in 100 lb. bags.

Filtration specialists for over 15 years

P. O. Box 928, Monterey, Calif. — Inquiries Invited

What a selling plus! And what a wonderful way to be sure of satisfied customers! Point out *you* use *slit-proof* Orangeburg *SP*—the only plastic pipe Guaranteed and Bonded for 20 years for cold water service. *Under terms of the Bond, repairs or replacements* (INCLUDING LABOR COSTS) *due to failure of the pipe will be made at Orangeburg's expense.* The Bond will be made out in your customer's name; for him to keep. After your *SP* installation is completed simply mail *"Request for Bond"* Form to Orangeburg. After approval, Bond will be sent direct to your customer. Why not take advantage of this amazing Bond offer on your next job. See your Authorized Orangeburg Wholesaler or write Dept. JA-79.

Approved for drinking water by National Sanitation Foundation

ORANGEBURG MANUFACTURING CO. • Orangeburg, New York • Newark, California

A Division of The Flintkote Company, Manufacturers of America's Broadest Line of Building Products

NSF LIFE

Professional Services

ALBRIGHT & FRIEL, INC.

Consulting Engineers

Water, Sewage, Industrial Wastes and Incineration Problems
City Planning, Highways, Bridges and Airports
Dams, Flood Control, Industrial Buildings
Investigations, Reports, Appraisals and Rates

Three Penn Center Plaza Philadelphia 2, Pa.

BLACK AND ASSOCIATES, INC.
BLACK LABORATORIES, INC.

Engineers and Chemists

Water, Sewerage, Hydrology, Waste Treatment
Complete Laboratory Services

700 S. E. 3rd St. Gainesville, Fla.

ALVORD, BURDICK & HOWSON

Engineers

Water Works, Water Purification, Flood Relief, Sewage Disposal
Drainage, Appraisals, Power Generation

20 North Wacker Drive Chicago 6

CLINTON BOGERT ENGINEERS

Consultants

CLINTON L. BOGERT — IVAN L. BOGERT
DONALD M. DITMARS — ROBERT A. LINCOLN
CHARLES A. MANGANARO — WILLIAM MARTIN

Water & Sewage Works — Incinerators
Drainage — Flood Control
Highways and Bridges — Airfields

145 East 32nd Street, New York 16, N. Y.

AWWA STANDARDS

for Water Works Materials

Compiled, approved and published by your Association to meet your needs.

Send for list of publications.

American Water Works Association, Inc.
2 Park Avenue New York 16, N.Y.

Bowe, Albertson & Associates

Engineers

Water and Sewage Works
Industrial Wastes—Refuse Disposal—Municipal Projects
Industrial Buildings—Reports Plans—Specifications
Supervision of Construction and Operation—Valuations
Laboratory Service

75 West Street New York 6, N.Y.

AYRES, LEWIS, NORRIS & MAY

Consulting Engineers

LOUIS E. AYRES — ROBERT NORRIS
GEORGE E. LEWIS — DONALD C. MAY
STUART B. MAYNARD — HOMER J. HAYWARD

Waterworks, Sewerage, Electric Power

500 Wolverine Building, Ann Arbor, Michigan

Brockway, Weber & Brockway

Engineers, Incorporated

George S. Brockway Roy E. Weber
George R. Brockway
Staff
H. L. Fitzgerald — Charles A. Anderson
Robert E. Owen — Ben E. Whittington
Thomas A. Clark — Ernest L. Greene
Thomas R. Demery

Civil, Structural, Sanitary, Municipal, Electrical, Land Planning

West Palm Beach, Florida Ft. Pierce, Florida

BLACK & VEATCH

Consulting Engineers

1500 Meadow Lake Parkway, Kansas City 14, Missouri

Water Supply Purification and Distribution; Electric Lighting and Power Generation, Transmission and Distribution; Sewerage and Sewage Disposal; Valuations, Special Investigations and Reports

BROWN AND CALDWELL

Civil and Chemical Engineers

Water—Sewage—Industrial Waste
Consultation—Design—Operation
Chemical and Bacteriological Laboratories

66 Mint Street San Francisco 3

Professional Services

BUCK, SEIFERT AND JOST

Consulting Engineers

WATER SUPPLY—SEWAGE DISPOSAL—
HYDRAULIC DEVELOPMENTS

Reports, Investigations, Valuations, Rates, Design, Construction, Operation, Management, Chemical and Biological Laboratories

112 E. 19th St., New York 3, N. Y.

BURGESS & NIPLE

Consulting Engineers

(Established 1908)

Water Supply, treatment and distribution
Sewage and industrial wastes disposal
Investigations, reports, appraisals, rates
Laboratory Municipal engineering
Supervision

2015 W. Fifth Ave. Columbus 12, Ohio

THE CHESTER ENGINEERS

Water Supply and Purification
Sewage and Industrial Waste Treatment
Power Plants—Incineration—Gas Systems
Valuations—Rates—Management
Laboratory—City Planning

601 Suismon Street
Pittsburgh 12, Penna.

BURNS & McDONNELL

Engineers—Architects—Consultants

4600 E. 63rd St. Trafficway
Kansas City 41, Missouri

CHAS. W. COLE & SON

Engineers and Architects

3600 E. Jefferson Blvd. South Bend, Indiana

2112 W. Jefferson St. Joliet, Illinois

JAMES M. CAIRD

Established 1898

C. E. CLIFTON, H. A. BENNETT

Chemist and Bacteriologist

WATER ANALYSIS
TESTS OF FILTER PLANTS

Cannon Bldg. Troy, N. Y.

CONSOER, TOWNSEND & ASSOCIATES

Water Supply—Sewerage
Flood Control & Drainage—Bridges
Ornamental Street Lighting—Paving
Light & Power Plants—Appraisals

360 E. Grand Ave. Chicago 11

CAMP, DRESSER & McKEE

Consulting Engineers

Water Works, Water Treatment,
Sewerage and Wastes Disposal,
Flood Control

Investigations, Reports, Design
Supervision, Research, Development

6 Beacon St. Boston 8, Mass.

DAY & ZIMMERMANN, INC.

Consulting Engineers

Valuations
Feasibility Studies & Reports
Rate Cases & Financial Studies
Supervisory Consulting Service

1700 Sansom St. Philadelphia 3, Pa.

CAPITOL ENGINEERING CORP.

Consulting Engineers

WATER WORKS—SEWAGE DISPOSAL—
AIRPORTS—DAMS—BRIDGES—ROADS
AND STREETS

Investigations, Reports, Appraisals, Rates, Survey and Design, Construction Supervision

Dillsburg, Pa.
Rochester, N. Y. Washington, D.C.

Fay, Spofford & Thorndike, Inc.

Engineers

Water Supply and Distribution — Drainage
Sewerage and Sewage Treatment—Incinerators
Airports — Bridges — Express Highways

Investigations Reports Valuations
Designs Supervision of Construction

Boston, Massachusetts

Professional Services

FINKBEINER, PETTIS & STROUT

Consulting Engineers

Water Supply, Water Treatment,
Sewerage, Sewage Treatment,
Bridges, Highways & Expressways

2130 Madison Avenue — Toledo 2, Ohio

GREELEY AND HANSEN

Engineers

Water Supply, Water Purification
Sewerage, Sewage Treatment
Refuse Disposal

220 S. State Street, Chicago 4

FREESE & NICHOLS

Fort Worth, Texas

FREESE, NICHOLS, TURNER & COLLIE

Houston — Port Arthur

Industrial and Municipal Engineering—Water Supply and Purification—Sewerage and Industrial Waste Treatment—Highways and Structures — Dams — Drainage Works — Airports—Investigations—Valuation—Design and Supervision.

GROUND WATER ASSOCIATES

Consulting Hydrologists and Engineers

Investigations, Reports and Recommendations on Underground Water Supplies. Preparation of Plans and Specifications.

Box 480 — JEfferson 6-0494
Norman, Oklahoma

FROMHERZ ENGINEERS

Structural—Civil—Sanitary

Four Generations Since 1867

Water Supply; Sewerage; Structures; Drainage; Foundations
Highways & Streets
Investigations; Reports; Plans and Specifications; Supervision

New Orleans

WILLIAM F. GUYTON & ASSOCIATES

Consulting Ground-Water Hydrologists

Underground Water Supplies
Investigations, Reports, Advice

307 W. 12th St.
Austin 1, Texas
Phone: GR-7-7165

GANNETT FLEMING CORDDRY & CARPENTER, Inc.

Engineers

Water Works—Sewerage
Industrial Wastes—Garbage Disposal
Roads—Airports—Bridges—Flood Control
Town Planning—Appraisals
Investigations & Reports

Harrisburg, Pa. — Philadelphia, Pa.
Pittsburgh, Pa. — Daytona Beach, Fla.

HASKINS, RIDDLE & SHARP

Consulting Engineers

Water—Sewage & Industrial Wastes—Hydraulics
Reports, Design, Supervision of Construction, Appraisals, Valuations, Rate Studies

1009 Baltimore Avenue — Kansas City 5, Mo.

GET YOUR COPY NOW!

A list of AWWA books, manuals, standards, and other publications may be had for the asking. Is your library complete?

American Water Works Association, Inc.
2 Park Avenue — New York 16, N.Y.

HAVENS & EMERSON

A. A. Burger — H. H. Moseley
J. W. Avery — F. S. Palocsay
E. S. Ordway — G. H. Abplanalp
A. M. Mock — S. H. Sutton
F. C. Tolles, Consultant

Consulting Engineers

Water, Sewage, Garbage, Industrial Wastes, Valuations—Laboratories

Leader Bldg. — Woolworth Bldg.
CLEVELAND 14 — NEW YORK 7

Professional Services

HAZEN AND SAWYER

Engineers

Richard Hazen Alfred W. Sawyer
H. E. Hudson, Jr.

Water and Sewage Works
Industrial Waste Disposal
Drainage and Flood Control

122 East 42nd Street, New York 17, N.Y.
3333 Book Bldg., Detroit 26, Mich.

C. E. JACOB

Groundwater Consultant

Water Supply, Drainage, Dewatering, Subsidence, Recharging, Salt-Water Control, Statistical Hydrology, Digital and Analog Computation

P. O. Box 347, Northridge, Calif.
Cable JACOBWELL Los Angeles
DIckens 5-4990

ANGUS D. HENDERSON

Consulting Engineer

Water Supply and Sanitation

330 Winthrop St., Westbury, New York
210-07—29th Ave., Bayside, New York

THE JENNINGS-LAWRENCE CO.

Civil & Municipal Engineers
Consultants

Water Supply, Treatment & Distribution
Sewers & Sewage Treatment
Reports—Design—Construction

1392 King Avenue, Columbus 12, Ohio

H. G. Holzmacher & Associates

Consulting Engineers

H. G. HOLZMACHER
R. G. HOLZMACHER S. C. McLENDON

Municipal Engineering
Water Supply & Treatment
Sewerage & Treatment
Water Analysis Laboratory

66 W. Marie Street, Hicksville, L. I., New York

JONES, HENRY & WILLIAMS

Consulting Sanitary Engineers

Water Works
Sewerage & Treatment
Waste Disposal

Security Bldg., Toledo 4, Ohio

HORNER & SHIFRIN

Consulting Engineers

E. E. Bloss V. C. Lischer

Airports, Sewerage & Drainage, Hydrology, Sewage & Industrial Waste Treatment, Water Supply & Treatment, Paving, Structures, Industry Engineering Services

1221 Locust Street, St. Louis 3, Mo.

HARRY J. KEELING

Consulting Engineer

Electrical—Mechanical—Corrosion

Investigations—Reports—Advisory Service
Mobile radio communication systems;
Special mechanical design problems;
Soil corrosion, Electrolysis,
Cathodic protection
of buried or submerged metal surfaces.

1718 Livonia Avenue, Los Angeles 35, Calif.

ROBERT W. HUNT CO.

Inspection Engineers

(Established 1888)

Inspection and Test at Point of Origin of Pumps, Tanks, Conduit, Pipe and Accessories

810 S. Clinton St.
Chicago 7, Ill.
and Principal Mfg. Centers

KENNEDY ENGINEERS

RICHARD R. KENNEDY ROBERT M. KENNEDY

Investigation—Design
Water Supply Water Purification
Sewage and Waste Treatment
Water Reclamation

604 Mission St., San Francisco 5
Tacoma Los Angeles Salt Lake City

Professional Services

DEAN S. KINGMAN
Consulting Engineer

Water Works
Sewerage & Treatment

153 University Avenue
Palo Alto, California

Look to the Journal Advertising Pages

for guidance when you require professional services or water works products. A "Buyers' Guide" appears in the final pages of this issue.

American Water Works Association, Inc.
2 Park Avenue New York 16, N. Y.

MORRIS KNOWLES INC.
Engineers

Water Supply and Purification,
Sewerage and Sewage Disposal,
Industrial Wastes, Valuations,
Laboratory, City Planning

Park Building Pittsburgh 22, Pa.

JOHN F. MANN, JR. AND ASSOCIATES
Consulting Groundwater Geologists

Investigations, Reports, Advice
on Underground Water Supplies

945 Reposado Drive La Habra, Calif.

KOEBIG & KOEBIG
Consulting Engineers Since 1910

Investigations, Reports, Designs
Water Supply & Water Treatment
Sewerage & Sewage Treatment
Municipal Engineering

3242 W. Eighth St. Los Angeles 5, Calif.

METCALF & EDDY
Engineers

Water, Sewage, Drainage, Refuse
and Industrial Wastes Problems
Airports Valuations
Laboratory

Statler Building
Boston 16

R. E. LAYTON & ASSOCIATES
Consulting Engineers

Hydraulic Structures
Water Supply–Storage–Distribution
Industrial and Domestic Waste Disposal–Drainage
Investigations, Reports, Plans, and Specifications

655 West Avenue 135th
San Leandro, California

JAMES M. MONTGOMERY
Consulting Engineer

Water Supply—Water Purification
Sewerage—Sewage and Waste Treatment
Flood Control—Drainage
Valuations—Rates
Investigations—Design—Operation

535 E. Walnut St. Pasadena, Calif.

LEGGETTE, BRASHEARS & GRAHAM
Consulting Ground Water Geologists

Water Supply
Dewatering
Recharging
Salt Water Problems
Investigations
Reports

551 Fifth Avenue New York 17, N. Y.

Nussbaumer, Clarke & Velzy, Inc.
Consulting Engineers

Sewage Treatment—Water Supply
Incineration—Drainage
Industrial Waste Treatment
Appraisals

327 Franklin St., Buffalo, N. Y.
500 Fifth Ave., New York 36, N. Y.

Professional Services

PARSONS, BRINCKERHOFF, HALL & MACDONALD

Civil and Sanitary Engineers

Water, Sewage, Drainage and Industrial Waste Problems.

Structures — Power — Transportation

165 Broadway New York 6, N. Y.

MALCOLM PIRNIE ENGINEERS

Civil & Sanitary Engineers

Malcolm Pirnie Ernest W. Whitlock
Robert D. Mitchell Carl A. Arenander
Malcolm Pirnie, Jr.

Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates

25 W. 43rd St. New York 36, N. Y.

THE PITOMETER ASSOCIATES, INC.

Engineers

Water Waste Surveys
Trunk Main Surveys
Water Distribution Studies
Water Measurement & Special Hydraulic Investigations

50 Church Street New York

LEE T. PURCELL

Consulting Engineer

Water Supply & Purification; Sewerage & Sewage Disposal; Industrial Wastes; Investigations & Reports; Design; Supervision of Construction & Operation

Analytical Laboratories

36 De Grasse St. Paterson 1, N. J.

RADER AND ASSOCIATES

Engineers and Architects

Water Supply, Treatment and Distribution
Sewers and Sewage Treatment
Investigations, Reports, Plans
Supervision of Construction and Operations

111 N. E. 2nd Ave., Miami 32, Florida
1025 Connecticut Ave. N. W.
Washington 6, D. C.
Apartado 4356 (Estación Exposición)
Panamá City, Panamá

THOMAS M. RIDDICK & ASSOCIATES

Consulting Engineers and Chemists

Municipal and Industrial Water Purification, Sewage Treatment, Plant Supervision, Industrial Waste Treatment, Laboratories for Chemical and Bacteriological Analyses

369 E. 149th St. New York 55, N.Y.
MOtt Haven 5-2424

RIPPLE & HOWE, INC.

Consulting Engineers

V. A. Vaseen B. V. Howe

Appraisals—Reports
Design—Supervision

Water Works Systems, Filtration and Softening Plants, Reservoirs, and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants, Refuse Disposal, Airports

833—23rd St., Denver 5, Colo.

ROBERT AND COMPANY ASSOCIATES

Engineering Division

Power Plants Water Sewage Plants
Airports Industrial Plants
Docks and Terminal Facilities
Reports Investigations

96 Poplar Street, Atlanta, Georgia

RUSSELL & AXON

Consulting Engineers

Civil—Sanitary—Structural
Industrial—Electrical
Rate Investigations

408 Olive St., St. Louis 2, Mo.
Municipal Airport, Daytona Beach, Fla.

J. HOMER SANFORD

Consulting Engineer—Hydrologist

39 Years of Groundwater Investigation

Groundwater Development, Recharge, Dewatering and Salt Intrusion
Analysis of Available Supply and Safe Yield
Litigation Reports and Testimony

1143 E. Jersey Street Elizabeth 4, N. J.

SERVIS, VAN DOREN & HAZARD

Engineers—Architects

Investigations · Design · Supervision of Construction · Appraisals

Water · Sewage · Streets · Expressways · Highways · Bridges · Foundations · Airports · Flood Control · Drainage · Aerial Surveys · Site Planning · Urban Subdivisions · Industrial Facilities
Electrical · Mechanical

2910 Topeka Blvd. Topeka, Kansas

J. E. SIRRINE COMPANY

Engineers Since 1902

GREENVILLE, SOUTH CAROLINA

Design, Reports, Consultations
Water Supply and Treatment
Sewage and Industrial Waste Treatment
Stream Pollution Surveys

R. KENNETH WEEKS

ENGINEERS

Designers • ***Consultants***

Water Supply and Purification
Sewerage and Sewage Treatment
Investigations and Reports
Supervision of Construction

Streets and Highways

6165 E. Sewells Point Road, Norfolk 13, Va.

SMITH AND GILLESPIE

Consulting Engineers

MUNICIPAL UTILITIES
AND PUBLIC WORKS

Complete Engineering Services

JACKSONVILLE, FLORIDA

ROY F. WESTON, INC.

Engineers—Biologists—Chemists

Water—Sewage—Industrial Wastes
Stream pollution—Air pollution
Surveys—Research—Development—Process Engineering—Plans and Specifications—Operation Supervision—Analyses—Evaluations and Reports

Newtown Square, Pa.

STANLEY ENGINEERING COMPANY

Consulting Engineers

Hershey Building **208 S. LaSalle St.**
Muscatine, Ia. **Chicago 4, Ill.**

1154 Hanna Building
Cleveland 15, Ohio

WESTON & SAMPSON

Consulting Engineers

Water Supply and Purification; Sewerage, Sewage and Industrial Wastes Treatment. Reports, Designs, Supervision of Construction and Operation; Valuations. Chemical and Bacteriological Analyses

14 Beacon Street **Boston 8, Mass.**

ALDEN E. STILSON & ASSOCIATES

(Limited)

Consulting Engineers

Water Supply—Sewerage—Waste Disposal
Bridges—Highways—Industrial Buildings
Studies—Surveys—Reports

245 N. High St. **75 Public Square**
Columbus, Ohio **Cleveland 13, Ohio**

WHITMAN & HOWARD

Engineers

(Est. 1869)

Investigations, Designs, Estimates, Reports, Supervision, Valuations, etc., in all Water Works and Sewerage Problems

89 Broad St. **Boston, Mass.**

WATER SERVICE LABORATORIES, INC.

Chemical Engineers

Specialists in Water Treatment
Consulting and Technical Services

Main Office: 615 W. 131 St., N. Y. 27, N. Y.
Offices also in: Phila., Wash., & Richmond

WHITMAN, REQUARDT & ASSOCIATES

Engineers ***Consultants***

Civil—Sanitary—Structural
Mechanical—Electrical
Reports, Plans
Supervision, Appraisals

1304 St. Paul St. **Baltimore 2, Md.**

J. STEPHEN WATKINS

J. S. Watkins G. R. Watkins

Consulting Engineers

Municipal and Industrial Engineering, Water Supply and Purification, Sewerage and Sewage Treatment, Highways and Structures, Reports, Investigations and Rate Structures.

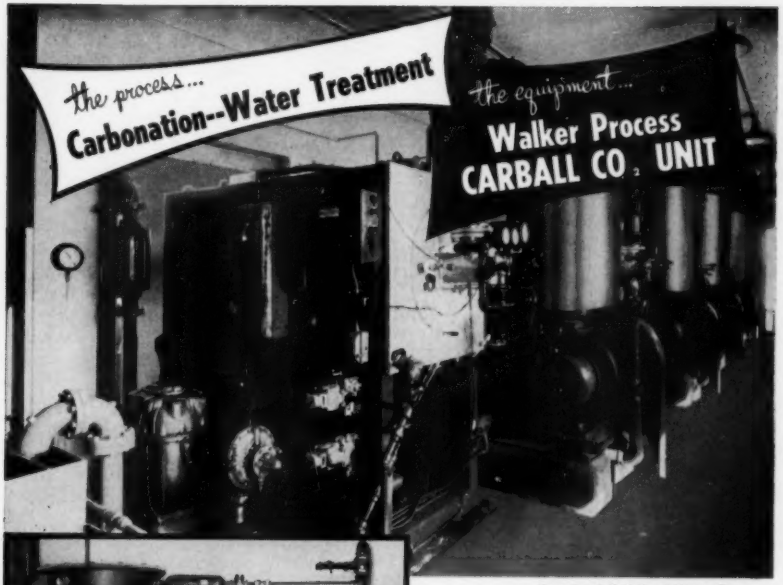
446 East High Street **Lexington, Kentucky**
Branch Offices
5402 Preston Highway, Louisville 13, Kentucky
107 Hale Street, Charleston, W. Va.

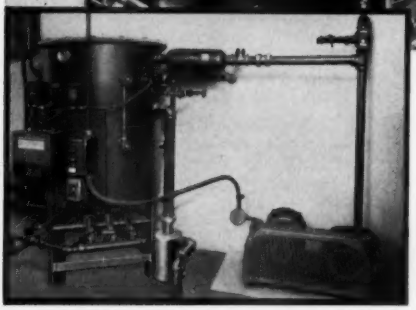
WILSEY & HAM

Engineers

Investigation and Design
Water Supply, Treatment and Distribution
Sewage Treatment and Disposal
Municipal Works and City Planning

111 Rollins Road **Millbrae, California**





Four size 4 Carballs at Kansas City, Mo. burn either gas or oil to produce max. of 40,000 lbs. CO_2/day. Size "O" unit at left produces 570 lbs. CO_2/day for Jefferson, Iowa Water Plant.

CARBALL
CO_2 UNIT

Walker Process now offers carbonation units for all lime softening plants from the very small to the largest. Sizes range from the new "OO" unit with minimum capacity of 55 lbs. CO_2/day to the No. 4 at maximum output of 10,000 lbs. CO_2/day.

Engineers can readily provide an entire carbonation system by simply specifying the appropriate size CARBALL in combination with Walker Process SPARJER diffusers . . . . . assuring

50% More CO_2
Clean, Tasteless Gas
100% Combustion
Unique Absorption Method
Economical Operation
Factory Tested Package System

Write for bulletins 7W83 - 7W85 and 7W88

WALKER PROCESS

WALKER PROCESS EQUIPMENT INC.
FACTORY • ENGINEERING OFFICES • LABORATORIES
AURORA ILLINOIS

Condensation

Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

LABORATORY METHODS

Some Improvements in the Method of Direct Titration of Sulfates. G. V. ZAVAROV. Zavodskaya Lab. (Moscow), **22**: 541 ('57). Detn. of sulfate by titration with barium chloride using alizarin red S as adsorption indicator was studied. Suspension of barium sulfate should be added before titration if sulfate cont. of the sample is low. Alizarin red S is then used as acid and adsorption indicator.—*WPA*

A Systematic Scheme of Semimicro Qualitative Analysis for Anionic Surfactants. H. HOLNESS & W. R. STONE. Analyst (Br.), **82**:166 ('57). Systematic scheme of semimicro qual. anal. is presented which permits identification of anionic surfactant as member of 1 of 21 groups of commoner anionic surfactants commercially available. Use is made of mixture of 2 dyestuffs. Disulphine blue V200 and Dimidium bromide, which, when used at 2 different pH values, give colored chloroform extracts in accordance with type of surfactant present. They may be used to indicate presence of fatty acids, sulfated or sulfonated surfactants, quaternary ammonium, or pyridium salts and cation-active amines when present as single substances.—*WPA*

Method of Evaluating Temperature in Lakes With Description of Thermal Characteristics of Convict Lake, California. N. REIMERS & B. D. COMBS. US Fish Wildlife Serv., Fishery Bul., No. 105:535 ('56). Studies of temp. in Convict L., alpine lake in eastern Calif., over a period of 2 yr, are used as basis for description of thermal characteristics including annual temp. cycle, distr. of temp., and thermal stratification in relation to morphometry and weather. Heat-budget method of assessing heat in lakes is affected by lake size, depth, and geographical location, which limit its use to general comparisons between large bodies of water. Method of increasing heat intensity (temp. summation) developed by authors has no such limitations. Data developed from temps. of Convict L. and other lakes of same drainage basin support conclusion that this method can be used to compare lakes of various sizes and situations over selected periods of time or for evaluating temp. in relation to other measures of lake productivity. Summation procedure is suggested in which base temp. is 32°F and summation units are day-deg. in excess of base.—*WPA*

Determination of Uranium in Natural Waters. L. L. THATCHER & F. B. BARKER. Anal. Chem., **29**:1575 ('57). U in natural waters is detd. by fluorophotometric anal. of samples fused with flux contg. 9% NaF, 45.5% Na_2CO_3, and 45.5% K_2CO_3. Aliquots of H_2O and H_2O "spiked" with 0.10 μg of U are evapd. in Pt dishes. These, with blank and stds., are fused with flux at not more than 650°F in an elec. muffle provided with agitation. Fluorescence of samples is measured in reflection-type fluorophotometer, and results are corrected for stray light, quenching, and U impurity in flux. Loss of U from sample before anal. is discussed. In presence of HCO_3^- ion such loss is minimized.—*CA*

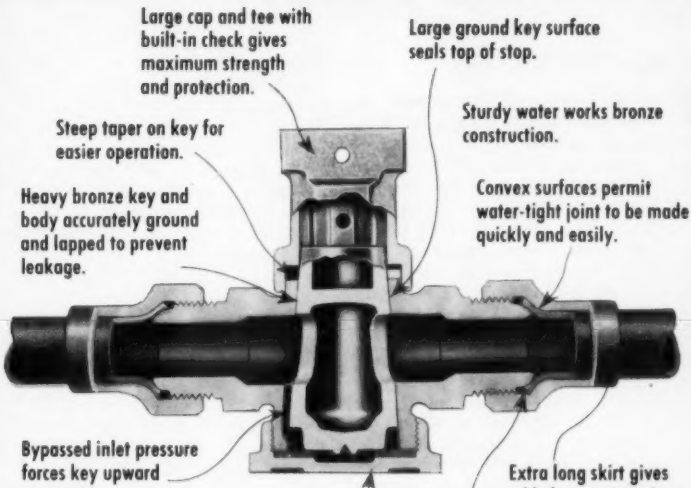
The Separation of Zinc From Some Other Elements by Means of Anion Exchange and Solvent Extraction, and Its Titrimetric Determination With Disodium Ethylenediaminetetraacetate (EDTA). J. A. HUNTER & C. C. MILLER. Analyst (Br.), **81**: 79 ('56). Details are given of prelim. exptl. work carried out on sepn. of zinc from other elements and its subsequent titrimetric detn. with EDTA, using Solochrome black as indicator. App. reagents, and method used in detn. of 0.1–5.0 mg zinc in mixts. are described. Procedure involves adsorption of zinc from 2*N* hydrochloric acid soln. by

(*Continued on page 66 P&R*)

MUELLER®

inverted key curb stops

easy turning . . . pressure tight . . . maintenance free


Large cap and tee with built-in check gives maximum strength and protection.
Large ground key surface seals top of stop.
Steep taper on key for easier operation.
Sturdy water works bronze construction.
Heavy bronze key and body accurately ground and lapped to prevent leakage.
Convex surfaces permit water-tight joint to be made quickly and easily.
Bypassed inlet pressure forces key upward to a seat.
Extra long skirt gives added support to pipe.
Opposed convex surfaces do not compress end of flange.
Base cap with leather seal prevents leakage.

H-15200 Inverted Key Curb Stop
Combined Cap and Tee with Check
Copper Coupling Connections
Sizes: ½" through 2"

For full details, contact your Mueller Representative or write to:

MUELLER CO.
DECATUR, ILL.

Factories at: Decatur, Chattanooga, Los Angeles;
In Canada: Mueller, Limited, Sarnia, Ontario

(*Continued from page 64 P&R*)

anion exchange, with prelim. treatment of resin with methyl arsonic acid to separate tin from zinc, and fixation of cadmium on resin by means of hydriodic acid; zinc is eluted from resin with water and nitric acid, and by solvent extraction as zinc pyridine thiocyanate it is sepd. from small amts. of gallium, indium, titanium, uranium, bismuth, tin, and lead. Zinc in eluate from resin column or from solvent extraction procedure is detd. titrimetrically with EDTA, using Solochrome black as indicator. Results are given for application of procedure to det. zinc in synthetic mixts., in alloys, and in glass.—*WPA*

BACTERIOLOGY

Availability of Iron and Manganese in Southern Wisconsin Lakes for the Growth of *Microcystis aeruginosa*. G. C. Gerloff & F. Skoog. Ecology, **38**:551 ('57). Availability of iron and manganese for growth and development of blooms of *Microcystis aeruginosa* in S. Wis. lakes has been investigated. Comparisons were made of cell conts. of these elements in algae collected from blooms with critical levels of elements for max. growth detd. in lab. Critical levels were approx. 100 ppm iron and 4 ppm manganese. Cell conts. of elements were in all cases so far in excess of these values that it is unlikely that availability of either element is factor in development of blooms of this species in lakes. Antagonistic relationships between manganese and iron and between calcium and manganese were demonstrated. These contribute difficulty of detg. exact levels of iron and manganese required in nutrient media, but are judged not to be serious enough to significantly affect accuracy of detns. of critical levels or conclusions drawn of availability of elements for growth of Microcystis. Manganese cont. of lake waters appears to reach levels high enough to be toxic to algae except for antagonistic action of calcium which is also present in relatively high concns.—*PHEA*

Nitrogen as a Limiting Factor for the Growth of *Microcystis aeruginosa* in Southern Wisconsin Lakes. G. C. Gerloff & F. Skoog. Ecology, **38**:556 ('57). Relative requirements and availability of nitrogen and phosphorus for growth of *Microcystis aeruginosa* in S. Wis. lakes has been evaluated by: (1) comparison of Microcystic growth in sterilized lake water enriched with nitrogen, phosphorus, and other essential elements singly and in various combinations, (2) by comparisons of min. nitrogen and phosphorus requirements of Microcystis as detd. in lab. culture expts. with quants. of these elements present in lake water, and (3) by comparisons of cell conts. of nitrogen and phosphorus in Microcystis collected from lake blooms with "critical levels" (min. cell conts. required for max. growth) established in lab. Critical levels of nutrients are to some extent function of carbohydrate cont. of algae cells, and procedure is presented for adjusting % of nitrogen cont. in accordance with tot. carbohydrate cont. Cell cont. comparisons showed that in all cases nitrogen supply was close to limiting and in several instances had become limiting for growth. All results indicated nitrogen to be present in far less abundant supply relative to need than phosphorus. Practical implications of results and possible usefulness of methods with reference to control of bloom production by removal of nitrogen or eventually other limiting nutrients from poln. sources are discussed briefly.—*PHEA*

The Bacterial Oxidation of Ammonia in the Sea. C. P. Spencer. J. Mar. Biol. Assoc. United Kingdom (London), **35**:621 ('56). During expts. on nitrifying behavior of surface water from Intern. Hydrographical Station E1 it was found that failure of samples of water to oxidize added ammonium-nitrogen to nitrite was due not to absence of nitrifying bacteria, but to lack of suitable nutrient conditions for their proliferation. Addn. of sterile diatoms or sterile hot-water extracts of diatom cells to water allowed nitrifying organisms to proliferate with concurrent oxidation of ammonia to nitrite. Naturally occurring nitrifying flora in water from Menai Strait (Wales) was capable of proliferation without addns. of diatom material but these organisms could not grow in E1 water unless diatom material was added. Nitrifying organisms in Menai Strait water were also capable of growing in E1 water if iron was added. It is suggested that failures by previous investigators to demonstrate presence of nitrifying bacteria in middle layers of open ocean waters may be due not to their absence but to failure to supply sufficient iron for appreciable growth of organisms in culture.—*WPA*

(*Continued on page 68 P&R*)

GRAVER BUILDS STANDPIPE FOR WATER EXPANSION PROGRAM

Part of a new $1½ million expansion program started last October by the Cuyahoga Falls, Ohio Water Department, is this new 750,000 gallon standpipe, designed, fabricated and erected by Graver. It stands 130′ high and provides water for the residents in eastern Cuyahoga Falls at a minimum of 50 pounds pressure. Graver craftsmanship and skill are nationally-known for fabricating standpipes, such as this, elevated water tanks and reservoirs. Call upon Graver for the solution to your water storage problem.

GRAVER TANK & MFG. CO.

DIVISION—UNION TANK CAR COMPANY

Plants and Offices Across America

EAST CHICAGO, INDIANA

GRAVER

TENTH EDITION

Standard Methods

• 1955 •

List price, $7.50. Price to members sending cash with order, $6.50

The new edition of *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes* is now available. The 522-page book—over 200 pages larger than its predecessor—includes new material on methods, theory, significance of results, and expected accuracy and sensitivity.

Published jointly by
APHA FSIWA AWWA

Send your order to:

AMERICAN WATER WORKS ASSOCIATION
2 Park Ave. New York 16, N. Y.

(*Continued from page 66 P&R*)

Aquatic Diptera as Indicators of Pollution in a Midwestern Stream. G. H. PAINE JR. & A. R. GAUFIN. Ohio J. Sci., 56:291 ('56). Tot. of 94 species of Diptera were collected and identified from Lytle Creek or its tributaries in SW Ohio from Jun. '51 to Jul. '52. These species were found in many different ecological niches in both clean and pold. sections of stream, many being highly selective in their habitat. Those species with special adaptations for obtaining oxygen from water surface such as the larvae of families *Calicidae, Syrphidae,* and *Stratiomyidae* were unaffected by low DO concns. in stream and occurred frequently and in large nos. in septic and recovery zones. Representatives of family *Chironomidae* were particularly adaptable to many different habitats in stream, with no. of species showing marked selection for specific ecological niches in each of life zones. Because of their adaptability and selectivity of habitat they constituted most important group of indicator organisms among Diptera in Lytle Creek. Presence of *Chironomus riparius, Glyptoten dipessp, Eristalis bastardi,* and *Culex pipiens* in large nos. was very characteristic of septic and recovery zones and their abundance in other similar streams may be interpreted as indicators of org. poln. Predatory chironomids such as *Anatopynia dyari* and *Pelopia stellata* had wider range and greater adaptability to different environmental conditions than any other species, except *Chironomus decorus,* and because of their widespread distr. their use as indicator organisms was distinctly limited. Considerable difference in the polnal. tolerances of 4 red-blooded chironomids existed with *Chironomus riparius* being confined to septic and recovery zones; *Stictochironomus varius* and *Microtendipes pedellus* to clean water areas; and *Chironomus decorus* being somewhat ubiquitous. Species restricted to definite and narrow habitats constituted much better indicator organisms than those species adaptable to both clean and pold. water conditions. Because all of species found in septic and recovery zones were also found in limited nos. in clean-water areas, those species restricted to latter areas have more value as indicators. On basis of Lytle Creek studies *Polypedilum illinoense, Microtendipes pedellus, Coelotanypus concinnus,* and *Endochironomus nigricans* are positive indicators of unpold. habitat when they are present.—*PHEA*

(*Continued on page 70 P&R*)

Pipe being primed at coating yard specially set up by Koppers Contract Coating Department for a large water supply project.

3/32" MAKES ALL THE DIFFERENCE

Steel water pipe will last much longer underground with the armor-like protection which a 3/32" coating of Bitumastic 70-B AWWA Enamel gives it. This corrosion-preventive coating is vital to the long-life of water lines.

Bitumastic Enamel has helped steel water lines set high flow capacity records of 40 years and more. Proven performance is one reason why so many water supply engineers are specifying steel pipe, lined and coated with Bitumastic 70-B AWWA Enamel, for their projects today. A lining of this enamel gives a uniformly smooth inside surface that has proved to have the highest flow coefficient available.

You can obtain more information about the economies of Bitumastic 70-B enameled steel pipe from Koppers Company, Inc., Tar Products Division, Dept. 110H, Pittsburgh 19, Pennsylvania.

KOPPERS

ONLY KOPPERS MAKES

BITUMASTIC

REG. U. S. PAT. OFF.

ENAMELS

(*Continued from page 68 P&R*)

CHEMICAL ANALYSIS

Analysis of the Mineral Waters of "La Providencia" of San Sebastian de Los Reyes (Madrid). R. CASARES. Anales Bromatol. (Madrid), **10**:175 ('58). H_2O was transparent, colorless, odorless, and alk. to phenolphthalein. pH was 8.26, diolymium 0.99906, fp lowering 0.012°F, and *N* 1.3320 at 19°F. Radioactivity corresponded to activity of 306 μc and Rn cont. was 18.36×10^{-10} g/l. Compn. of water (mg/l) was $NaHCO_3$ 175.77, $Ca(HCO_3)_2$ 6.23, $Fe(HCO_3)_2$ 1.11, Na_2CO_3 32.01, Na_2SO_4 15.33, $MgSO_4$ 0.68, NaCl 15.15, SiO_2 10.68, NaF 3.36; total 260.32.—*CA*

Study of the Therapeutic Mineral Resources of the Moldavian S.S.R. K. A. NIKOGOSYAN. Sbornik Trudov Moldavsk. Nauch.-Issledovatel. Inst. Epidemiol., Mikrobiol., i Gigieny (USSR), **1**:13 ('56). Description is given of 16 Moldavian springs which have application possibilities from balneological point of view. Anals. are presented on the basis of KURLOV's formulas. Presence of low mineralization owing to HCO_3^-, SO_4^{--}, Na^+, and Mg^{++} (0.8–1.5 g/l) is noted; thermal springs with water temps. of 18–22°F and S springs with a H_2S concn. of 2–200 mg/l and increased mineralization of 3.3–17.1 g/l are described.—*CA*

Chemical Composition of the "Naftusya" Waters in the Truskavets Spa. K. G. GAYUN & T. F. LEVCHENKO. Gidrokhim. Materialy (Moscow), **27**:66 ('57). These waters contain org. materials, such as phenols, which are derived from petroleum wells nearby. Waters also contain H_2S, CO_2, O, N, and CH_4 of which especially H_2S is changed to a greater extent, as formation of SO_4^{--} is favored. Other materials in waters are Ba, Si, Fe, Mn, Al, V, Cu, Ti, Sr, and B, in addn. to common mineral components. Assay of Sr is remarkably high. Definitely absent (spectroscopically) are Pb, Sn, Ni, Cd, Ag, Co, As, Hg, Cr, Sb, Mo, Zr, Zn, Be, P, W, and Bi. Waters are hardly radioactive at all.—*CA*

(*Continued on page 72 P&R*)

for Public Water Fluoridation

Sodium Silicofluoride – 99%
(Powder)

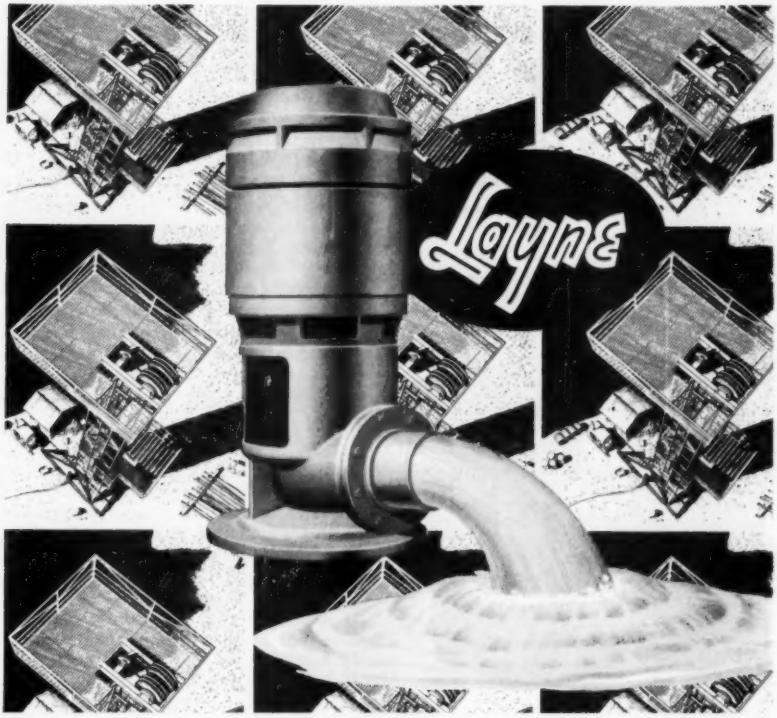
Sodium Fluoride – 98%
(Powder or Granular)

Meet AWWA specifications

White or tinted blue • Dry and free-flowing
Minimum of storage space • Available in bags and drums
Minimum of dust in handling

THE AMERICAN AGRICULTURAL CHEMICAL COMPANY
100 Church Street, New York 7, N. Y.

AA QUALITY



Layne pumps top more producing water wells

Layne Pump Design, manufacture and installation are only part of the complete water service offered by the Layne organization. Other services include: Initial surveys, explorations, recommendations, site selection, foundation and soil sampling, well drilling, well casings and screens, gravel wall wells, construction of water systems, complete research staff and facilities, maintenance and service, chemical treatment of water wells, water treatment. *Write for Bulletin No. 100.*

World's Largest Layne Water Developers

LAYNE & BOWLER, INC., MEMPHIS

General Offices and Factory . Memphis 8, Tennessee

Water Wells • Vertical Turbine Pumps • Water Treatment

Ferri-Floc
FERRIC SULFATE
The Superior COAGULANT
With The Plus FACTORS
Excellent taste and odor control
Increased filter runs
Coagulation over wide pH ranges
Rapid floc formation
Turbidity removal
Color removal
Manganese and Silical removal
Bacteria removal
Ease of operation
Economy
WATER TREATMENT
Efficient Coagulation at Surface or Well Water . . . Effective in lime soda-ash softening . . . Adaptable in treatment of all industrial applications.
Ferri-Floc
SEWAGE TREATMENT
Coagulates over wide pH ranges and provides efficient operation regardless of rapid variations of raw sewage . . . Very effective for conditioning sludge prior to vacuum filtration or drying on beds.
Ferri-Floc gives smoother, more efficient and trouble free operation. Whatever your particular water treatment problem may be, you can depend on Ferri-Floc doing a superior job and doing it efficiently and economically—Ferri-Floc is a free flowing granular salt which can be fed with few modifications through any standard dry feed equipment. It is only mildly hygroscopic, thereby permitting easy handling as well as storage in closed hoppers over long periods of time.
FREE BOOKLET Let us send you without charge, a 38-page booklet that deals specifically with all phases of coagulation—just send us a postal card.
COPPER SULFATE
COPPER SULFATE safely controls about 90% of microorganism normally encountered in water treatment plants efficiently and more economically than any other chemical.
SULFUR DIOXIDE
SULFUR DIOXIDE SO_2
SULFUR DIOXIDE is used most effectively for dechlorination in water treatment and to remove objectionable odors remaining after purification.
TC
TENNESSEE CORPORATION
617-629 Grant Building, Atlanta, Ga.

(*Continued from page 70 P&R*)

AQUATIC ORGANISMS

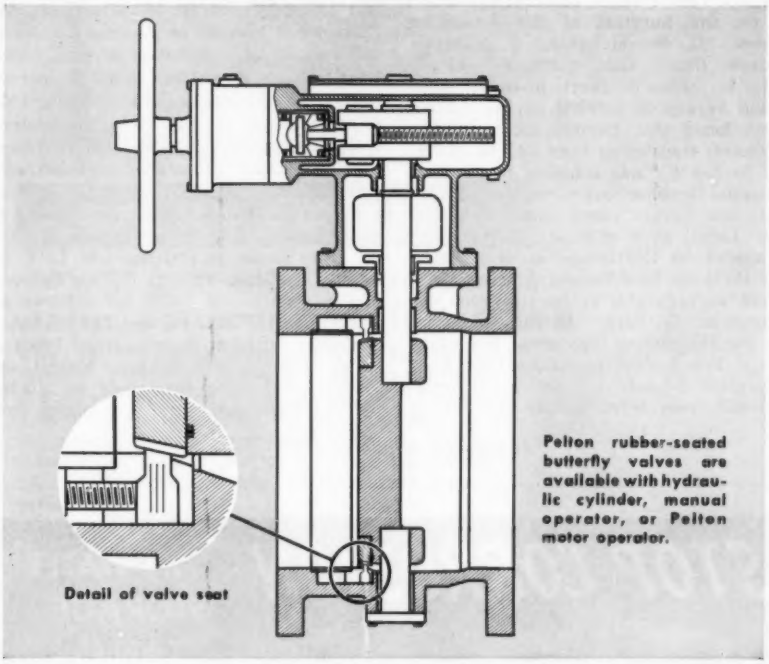
The Ecology of the Macroscopic Bottom Fauna in Lake Texoma (Denison Reservoir), Oklahoma and Texas. J. E. SUBLETTE. Am. Midland Naturalist, **57**:371 ('57). Water of res. circulates almost continuously throughout yr and there is no concn. zone of profundal organisms. 87 kinds of macroscopic benthic invertebrates were found, 70 of these being insects. Qual. and quant. distr. of bottom fauna followed closely character of substration which, in turn, was dependent primarily upon nature of original lake basin. Min. standing crop of bottom fauna occurred in late summer and max. occurred in late winter and early spring. —*PHEA*

Preliminary Observations on the Lowering of Dissolved Oxygen by Sodium Sulfite and Its Effects on Certain Fishes, With Particular Reference to Problems in Fish Management. J. R. WESTMAN & J. V. HUNTER. Progressive Fish Culturist, **18**:126 ('56). Lab. and field expts. on use of sodium sulfite to reduce concn. of DO have indicated that this method may be useful as means of salvaging and thinning fish pops. in ponds and shallow lakes. Method is nontoxic and renders pond unsuitable for aquatic life for little more than 1 day. Short time after addn. of sulfite, fish came to surface and began to gulp and could then be caught easily by hand or with net. All fish caught during this period revived when transferred to fresh water. No injury resulted to young bass subjected to this treatment at least 3 times within 1 wk. Duration of "catchability period" and period of time before its onset varied with dose of sulfite. —*WPA*

An Ecological Study of Lower San Gabriel River, California, With Special Reference to Pollution. D. J. REISH. Calif. Fish Game, **42**:1:51 ('56). In '52 and '54, phys., chem., and biol. surveys were carried out near mouth of San Gabriel R., Calif., both before and after section had been diked and excavated. Within excavated area estuarine invertebrates were found in '54, but were not present in '52. It appeared, however, that polg. material was again beginning to accumulate on bottom in this area. In unaltered portion of river which was similar in

(*Continued on page 74 P&R*)

Get longer life and trouble-free performance with Pelton rubber-seated butterfly valves



Pelton rubber-seated butterfly valves are available with hydraulic cylinder, manual operator, or Pelton motor operator.

A 6-in. test valve under 50 psi with a flow corresponding to a velocity of 16 ft. in the adjacent 6-in. pipe was recently operated through 12,500 cycles (10,000 with rubber seat ring downstream of valve operating shaft, 2500 with it upstream). Periodic checks at frequent intervals revealed that the valve was absolutely droptight throughout the entire test. Similar tests conducted under 125 psi demonstrated equally outstanding performance of these butterfly valves.

Manufactured in strict accordance with AWWA standards, Pelton rubber-seated butterfly valves offer the following significant advantages:

- **Compactness**
- **Ease of operation**
- **Low maintenance**
- **Greater net flow area (lower head losses than for comparable size valves)**

In addition to butterfly valves, Pelton manufactures impulse turbines, reaction type turbines, hydraulic turbine governors, spherical valves, pressure regulators, surge suppressors, waterworks valves, large centrifugal pumps, duplex strainers, dynamic balancers, etc. For descriptive illustrated bulletins, write Pelton Division (B-L-H), 2929 Nineteenth Street, San Francisco 10, Calif., or Eddystone Division (B-L-H), Phila. 42, Pa.

Pelton Division San Francisco, Calif.

BALDWIN · LIMA · HAMILTON

Hydraulic turbines • Valves • Governors • Centrifugal pumps

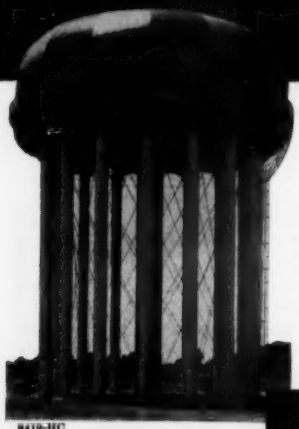
(*Continued from page 72 P&R*)

both yr river bottom was essentially sterile zone devoid of animal life. Sources of waste waters, both domestic and industrial, are discussed.—*WPA*

Effects of Temperature, Salinity, and Oxygen on the Survival of the American Lobster. D. W. McLeese. J. Fisheries Research Board Can. (Ottawa), 13:247 ('56). In studies on effects of temp., salinity, and oxygen on survival of Am. lobster it was found that thermal acclimatization for lobsters transferred from 14.5 to 23.0°C (58.1 to 73.4°F) was complete in 22 days. Substantial acclimatization to low salinity and to low oxygen concn. occurred within 1 wk. Lethal levels of these 3 factors were not altered by differences in size within range 16–34 cm, by difference in areas where lobsters were caught, or by starvation for as long as 57 days. Moulting lobsters were less resistant to high temp., low salinity, and low oxygen conditions than were hard-shelled lobsters. Upper lethal temp. levels and lower lethal salinity and oxygen levels were investigated for hard-shelled lobsters acclimatized to each of 3 levels of temp. (5, 15, and 25°C, or 41, 50, and 77°F), salinity (20, 25, and 30/1,000), and oxygen (2.9, 4.3, and 6.4 mg/l). Upper lethal temp. was raised by increase in thermal acclimatization and lowered by decrease in salinity and oxygen acclimatization levels. Lower lethal salinity concn. was raised by increase in level of thermal acclimatization and decrease in level of oxygen acclimatization; it was lowered by acclimatization to reduced salinity. Effect of salinity acclimatization was not always same but depended on temp. Lower lethal oxygen concn. was raised by either increase in temp. or decrease in salinity. The lower lethal temp. was 1.8°C for lobsters acclimatized to 17°C (35.2 and 62.6°F, resp.), and 5.0°C for lobsters acclimatized to 27.5°C (41 and 81.5°F, resp.). Ultimate and max. or min. lethal levels of temp., salinity, and oxygen, highest and lowest lethal levels that could be attained by acclimatization, were interpolated from

(*Continued on page 78 P&R*)

STOP CORROSION . . . IN WATER STORAGE TANKS



with Harco CATHODIC PROTECTION SYSTEMS

Everyday, electrolytic corrosion damages thousands of dollars worth of water storage tanks. Harco specialists can protect your investment with a cathodic system engineered to meet your needs.

Harco job-engineered installations include tests, drawings, materials, and installation as well as periodic maintenance services.

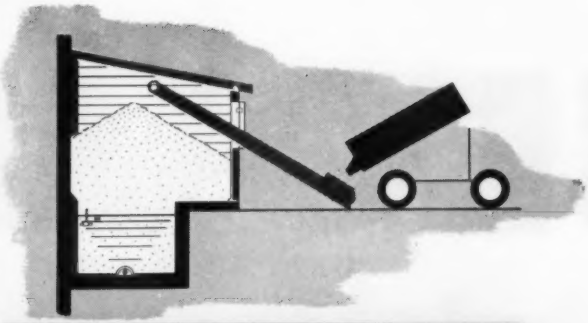
8419-HC

Write today for catalog or call VUlcan 3-8787.

Harco

THE HARCO CORPORATION

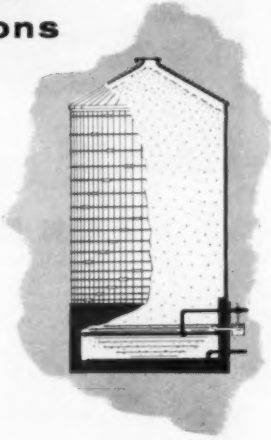
4593 East 71st St. • Cleveland 25, Ohio



BRINE LEVEL

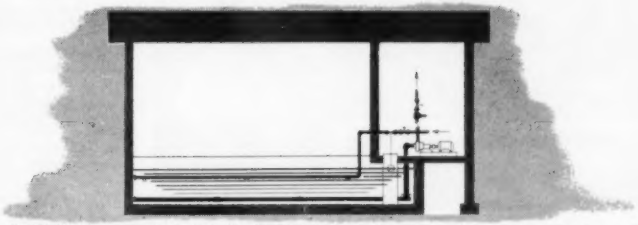
How it can affect design of water softening installations

What's the best brine level for a 500-gallon-per-hour salt dissolver? Your answer is bound to influence the type of dissolver construction needed, as well as the cost of operating the equipment. The lower the level, the less expense there will be in waterproofing the bottom portion of the dissolver. But too low a level can seriously reduce brine-making efficiency, and thus boost brine-making costs.



It is essential, therefore, to reach the best compromise between original construction cost and subsequent operating expense by specifying the correct brine level. Here's where International Salt Company is ready to help. 50 years of experience and continuing research in all phases of salt handling and brine production make International the leading authority on matters concerning salt purchase, storage and dissolving for regenerating ion exchangers. This knowledge is especially valuable in view of the ever-growing amounts of brine being used today.

Service and research are the extras in STERLING SALT



INTERNATIONAL SALT CO., INC., SCRANTON 2, PA. • **Sales Offices:** Atlanta, Ga. • Baltimore, Md. • Boston, Mass. Buffalo, N. Y. • Chicago, Ill. • Cincinnati, O. • Cleveland, O. • Detroit, Mich. • Newark, N. J. New Orleans, La. • New York, N. Y. • Philadelphia, Pa. • Pittsburgh, Pa. • Richmond, Va. • St. Louis, Mo.

CLOW

UNDER WATER

4-man crew lays 1500 feet a day of CLOW 8" Bell-Tite Joint cast iron pipe through Florida swampland—often in 3 feet of water. Hancock Pipe Co., Clearwater, Fla., contractor.

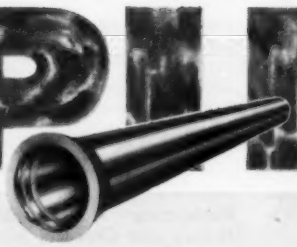
AT 14° BELOW 0

Despite rocky terrain and digging through 2 to 3 feet of frost, workers were able to lay 50% as much 12" Bell-Tite pipe a day at 14 below zero as under normal conditions. Trench was 11 feet deep. Nels Nelson & Sons, Duluth, Minn., contractors.

OR IDEAL CONDITIONS

Laying 2000 feet a day of CLOW Bell-Tite Joint pipe under ideal conditions at Boca Raton, Florida. Reilly-Bates Corp., Pompano Beach, Fla., contractors. Black & Associates, Gainesville, Fla., consulting engineers.

CAST IRON PIPE



PROVED...

CLOW Bell-Tite® JOINT

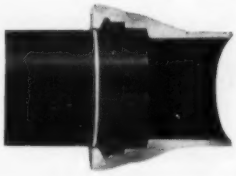
CAST IRON PIPE

saves time and money under all installation conditions

Clow Bell-Tite Joint costs less to buy and less to install. Assembly is easy and rapid and the rate of installation depends only on the speed with which the trench can be excavated.

A single molded rubber gasket is the only accessory required. No bolts, no nuts, no followers, no couplings, no extras to buy. Clow Bell-Tite pipe is available from 3" to 24" in any thickness or weight in accordance with ASA, AWWA, or Federal specifications.

Clow Bell-Tite Joint is easily assembled—just wipe clean, lubricate and push spigot into the bell. When painted yellow stripe is no longer visible, joint is pressure tight.



OUR 81st YEAR
1878 • 1959

It will pay you to know the savings in time and money CLOW Bell-Tite Joint Cast Iron Pipe makes possible. Let us give you complete information on its many advantages.

CLOW CAST IRON PIPE

JAMES B. CLOW & SONS, INC.
201-299 North Talman Avenue, Chicago 80, Illinois

Subsidiaries:
Eddy Valve Company, Waterford, N.Y.
Iowa Valve Company, Oskaloosa, Iowa

(*Continued from page 74 P&R*)

results. These measures were used to integrate lethal levels of 3 factors into single 3-dimensional graph which describes boundary of lethal conditions for lobsters that are exposed to 3 factors operating together.—*WPA*

The Relation of Phytoplankton Periodicity to the Nature of the Physicochemical Environment, With Special Reference to Phosphorus. II. Seasonal and Vertical Distribution of the Phytoplankton in Relation to the Environment. A. TUCKER. Am. Midland Naturalist, **57**:334 ('57). Nutrient elements, other than phosphorus, which are combined with ferric complexes, appear to be responsible for phytoplankton pulses occurring after each overturn in deeper lakes. These nutrients appear to be liberated from mud as sol. complexes only when lake bottom becomes depleted of oxygen. Magnitude and duration of each phytoplankton pulse occurring after overturn may depend upon magnitude, duration, and time of nutrient liberation from mud. Shallow lakes probably always have adequate supply of nutrients, and factors other than nutrients seem to control formation of plankton pulses. These factors may not stimulate plankton growth but rather inhibit production already in operation.—*PHEA*

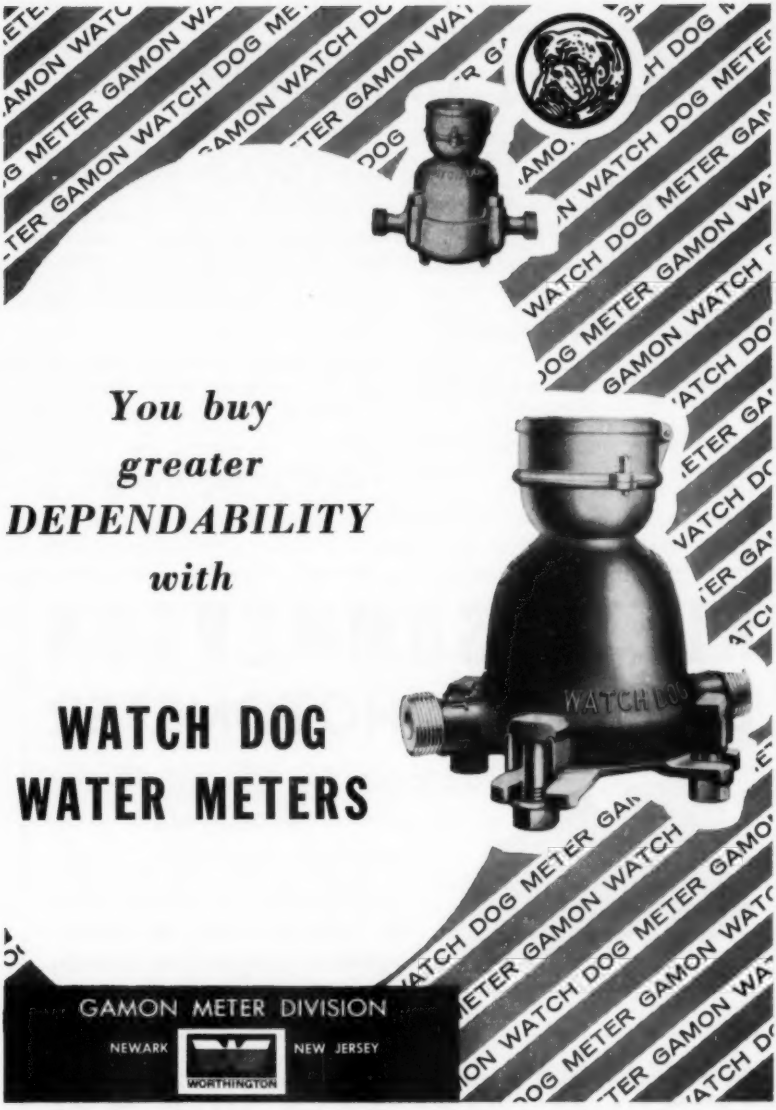
Study on the Quality of Fresh Waters of Puerto Rico Relative to the Occurrence of *Australorbus glabratus*. H. W. HARRY; B. G. CUMBIE; & J. M. DE JESUS. Am. J. Trop. Med. Hyg., **6**:313 ('57). More than 130 anals. of P.R. fresh waters were analzed in effort to relate observed range of certain environmental factors to natural habitat of *A. glabratus*. Temp. of waters ranged from 21 to 35°F and pH from 6.0 to 9.1; snail was found in waters throughout these ranges. Snail occurred in waters contg. max. concns. observed of CO_3, HCO_3, Cl, SO_4, Ca, and Mg; these max. concns. were 415; 415; 2,150; 133; 129; and 103 ppm, resp. It generally but not invariably was absent from waters having less than 150 ppm dissolved solids. Snail can be maintd. at least 2 wks in redistd. H_2O. About 0.1 ppm Cu in distd. H_2O produced distress in snail within few hr. Cu concns. in natural waters ranged from 0 to 0.330 ppm; most instances of Cu concn. >0.020 occurred in waters of <150 ppm dissolved solids. Snail was not found in waters whose Cu conts. were 0.200–0.330 ppm. It is suggested that presence of Cu, and perhaps other heavy metals, may be responsible for absence of snail in most waters. Large excess of CO_3 and HCO_3 over Cl and SO_4 is suggested as related to absence of snail in flowing waters on limestone.—*CA*

POLLUTION CONTROL

Reclaiming Rolling Mill Oils Saves Money and Corrects River Pollution. E. E. MCDOLE. Wastes Eng., **27**:327 ('56). Disposal of rolling mill wastes at the Trentwood, Wash., plant of Kaiser Aluminum and Chem. Corp. was changed due to uncontrollable aspects of practice of pumping sol. oils into open pit for soil seepage. Cold mills waste consists of mineral oils, plus additives, and solvent for washing roll oil from sheets. Practice of burning waste as No. 6 fuel oil was replaced by filtration and distn. Solvent and roll oil is reused. Process makes profit. Mixt. from each cold mill flows to sump. These are centralized and pumped to large holding tank. Waste is fed to still and fractionating tower. Condensed solvent is pumped to carbon tube water solvent separator. Solvent is purified by filtration through fuller's earth and reused. Continuous stream of coolant oil is taken from bottom of still, cooled and reused. Filtration is necessary to control foaming. Sol. oil solns. from hot line are sepd. by sulfuric acid. Broken emulsions from emulsion breaking tank overflow to separator. Heat is supplied to emulsion before entering breaking tank and also top portion (oil phase only) of oil-water sepg. tank. Water from bottom of tank passes through secondary settler to sewer. Oil from separator flows into another tank, is heated, dried, and burned as No. 6 fuel. Emulsion breaking tank goes to sol. oil storage. This system just about pays depn. and operation costs. River diln. is considered satisfactory for preventing damage. Flow chart for sol. oil plant is shown.—*PHEA*

Contamination of Drinking Water by Mineral Oils. W. ZIMMERMANN ET AL. Z. Hyg. Infektionskrankh. (Berlin), **142**:322 ('56). This paper draws attention to dangers of poln. of soil and of water supplies by mineral oils. These risks are likely to

(*Continued on page 80 P&R*)


You buy
greater
DEPENDABILITY
with
WATCH DOG
WATER METERS
GAMON METER DIVISION
NEWARK
NEW JERSEY
WORTHINGTON

(*Continued from page 78 P&R*)

become greater with increasing use of these fuels and their products. References are given to accts. of no. of cases of such poln. which have occurred. Considerable description is given of accident at Trier (W. Ger.) when 1,000,000 l (264,200 gal) of kerosene exploded. Difficulties of chem. investigation are stated, for no chem. anal. is capable of deterg. mining small amts. of petrol and similar products which may be sufficient to make water unpalatable. There is extensive description of results of routine chem. water anal. at different points in water system, of biol. investigations, and of the geol. configuration of neighborhood of accident. Measures that should be taken to prevent poln. of soil and water by mineral oil products are discussed.—*PHEA*

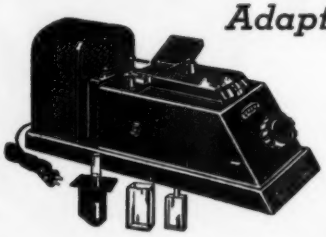
Organic Contaminants Affecting the Quality of Water. F. M. MIDDLETON & A. A. ROSEN. Public Health Repts. (US), **71**: 1125 ('56). Water qual. is seriously affected by contamn. from org. materials. Both drinking water and industrial supplies are impaired. Apart from nuisance and deprivation caused by effects on drinking water, it is conceivable that physiological effects may result from high concns. of these materials in public water supplies. At what concn. material such as those isolated from drinking water constitute hazard is not known. Many of org. materials in water have not yet been isolated or identified. Methods for studying these materials have been indicated and some of results outlined. In view of increased industrialization, increased water use, and present lack of knowledge of natural pollutants tot. effects of org. chems. on water qual. and means for control of materials demand increased attention.—*CA*

Ozone Method for Destruction of Phenols in Petroleum Waste Waters. S. J. NIEGOWSKI. Sew. & Ind. Wastes, **28**:1266 ('56). Ozone method for destruction of phenols in petroleum wastes offers several advantages. Ozone treatment adds only oxy-

(*Continued on page 82 P&R*)

KLETT SUMMERSON
ELECTRIC PHOTOMETER

Adaptable for Use in Water Analysis



Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined

KLETT MANUFACTURING CO.
179 EAST 87th STREET · NEW YORK, N. Y.

USE NORTHERN GRAVEL
for
RAPID SAND FILTER

FILTER SAND SPECIFICATIONS are carefully laid out. The Effective Sizes and Uniformity Coefficients used by Consulting Engineers and also recommended by the American Water Works Association are the result of long years of research and experience.

The Northern Gravel Company is equipped to give you prompt shipment whether it be one bag or many carloads, exact to specification. Filter sand can be furnished with any effective size between .35 MM and 1.20 MM.

CHEMICAL QUALITY of the filter sand is also important. It must be hard, not smooth and free of soluble particles. This requires perfect washing, and grading facilities. We have every modern device for washing, drying, screening and testing.

FILTER GRAVEL supporting the Filter Sand Bed must be, in turn, properly graded to sizes calculated to support the Filter Sand, and be relatively hard, round and resistant to solution.

The new Northeast Station in the City of Detroit, recently completed, is one of the major projects included in the water department's expansion program. The Northern Gravel Company furnished 120 carloads of filtering materials for the 48 rapid sand filters incorporated in this plant.

Northern Gravel has no equal in facilities and our reserves of both sand and gravel are inexhaustible. Northern Gravel Company has been in business over 40 years. We guarantee uniformity of products and our records enable us to duplicate your requirements on short notice. Our location is central and we have commodity rates in every direction.

NORTHERN GRAVEL COMPANY

Muscatine, Iowa

P.O. Box 307 **Phone: Amherst 3-2711**

(Continued from page 80 P&R)

gen to wastes. This means that high ozone dosages will not change character of wastes by introduction of another chem. Reduction of BOD and COD accompanies phenols destruction. Toxicity due to phenol is reduced in same proportion as phenols are destroyed. What might be called "super-ozonation" for complete phenols destruction is usually unnecessary. Even with partial ozone treatment there will be corresponding reduction in odor and toxicity. At those refineries where phenol-free process or cooling water is available for diln. only partial ozonation would be required for practical and satisfactory treatment. Treatment plant effluent having phenols residual of several ppb can be obtained by proper diln. of partially ozonated phenolic wastes.—*PHEA*

Biological Purification of Polluted Water in Soil. J. K. BAARS. Bul. Centre Belge Etude et Document. Eaux (Liege), **36**:75 ('57). In best situations fecal poln. of soil can be mineralized completely. When conditions are less favorable poln. can be carried deeper and deeper into soil. In such cases diln. is necessary but there may be insufficient pptn. to effect this. By judicious choice of circumstances in which infiltration will be carried out, following quick reduction in passage in sandy soil in presence of free or nitric oxygen, it is not only possible to obtain water of good qual., but also to know that certain margin of safety exists in each biol. system.—*PHEA*

Combined Effect of Water Purification Processes on the Removal of *Histoplasma capsulatum* From Water. D. F. METZLER; C. RITTER; & R. L. CULP. Am. J. Pub. Health, **46**:1571 ('56). Processes of plain sedimentation, coagulation, settling, rapid sand filtration, and chlorination, as practiced in conventional water filtration plants, have been applied in series in lab. to sterilized Kansas R. water inoculated with spores of *H. capsulatum*. Combined processes completely removed all viable spores even before chlorination treatment. Membrane filter technic was suitable for growth and enumeration of fungus colonies in lab.—*PHEA*

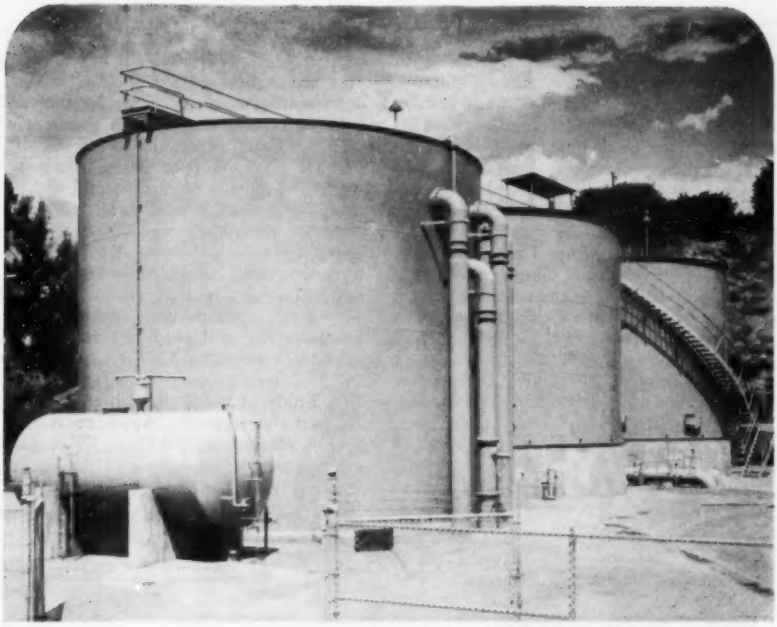
River Pollution. Calculation and Measurement of the Capacity of Self-Purification of Fermentable Organic Matter. E. LECLERC; P. BEAUJEAN; & F. DEVLAMINCK. (Liege Univ., Belg.). Rev. tech. luxembourg. (Lux.), **48**:174 ('56). Attempt is made to establish method to det. poln. and self-purifying power of river to obtain water of sufficient purity for water-consuming food industries. Principal factors to be considered are concn. of org. matter, bact. activity in self-purif., kind of org. matter, speed and turbulence of river, and chlorophyll activity. Curves of O cont. of river, and distr. along its course are given.—*CA*

Study of River Pollution. E. LECLERC; P. BEAUJEAN; & F. DEVLAMICK. Bul. Centre Belge Etude et Document. Eaux (Liege), **34**: 281 ('56). Purpose of such studies is maint. of proper amt. of DO in stream. Several theories are used for calcn. of required DO. Lab. control and field observation are used to det. effective DO. Study of org. matter concn., bact. activity or self purif. capac., nature of org. matter present, turbulence and speed of flow, diln., and activity of chlorophyllous organisms are used in detg. factors involved. Measurement of acceptable charge can be made by general observations. Spot checking in field is only way to insure maint. of adequate DO in water of rivers.—*PHEA*

Some Methods Currently Employed to Reduce River Pollution. J. B. K. LEV. Commonwealth Engr. (Austral.), **45**:3: 62 and **45**:4:61 ('58). Author briefly outlines fundamental basis of poln. defines object of purif., gives summary of methods of purif., and discusses some biol. and 3rd-stage methods. Author refers to trade waste problems, with particular attention to radioactive wastes. Indication is given of cost of purif. Constitution and functions of river boards are outlined. Impracticability of any universal standard of purif. is pointed out and need to draw up stds. for particular rivers or of sections of rivers is stressed.—*PHEA*

Quality of River Water and Its Pollution. III. The River Ichi. S. OKADA & K. UESUGI. Himeji Kogyo Daigaku Kenkyu Hokoku (Jap.), **8**:78 ('58). Water of river is pold. with waste water from various factories, paper mill, many tanneries, and seasoning-mfg. factory. Chem. examn. of river water showed increased amt. of sulfides, org. substances, and floating matters. Majority of these impurities disappeared upon flow of several km (1 km = 0.62 mi), Amt. of O in water was so small that fish could hardly

(Continued on page 84 P&R)



STEEL is your best bet for reliable water storage!

No matter what your water storage requirements are, you can count on steel to solve the problem quickly, efficiently and economically—steel tanks are built to last, and only steel tanks are backed by American Water Works Association standards. These are the only standards which assure you maximum protection in design and close control of material and craftsmanship. Welded steel construction combines strength, tightness, elasticity and economy for long, trouble-free service.

STEEL PLATE FABRICATORS ASSOCIATION

105 West Madison Street
Chicago 2, Illinois

(Continued from page 82 P&R)

live. **IV. The River Yumesaki.** Ibid., **8**: 82 ('58). This river is pold. with waste water from glue-mfg. works. Inorg. substances dissolved in water, mainly sulfates, chlorides, and lime, were 1.7 times greater than that in uppermost stream. Residues on evapn., sulfates, and lime were higher in winter than in summer; chlorides were less in summer and fall. Little or no difference was observed in alky. and acidity. and amt. of $KMnO_4$ consumed was less than 8 ppm throughout yr. **V. The River Chikusa.** Ibid., **9**:25 ('58). R. Chikusa flows thru mountainous, wooded regions in the W.–S. part of Hyogo Prefecture. Cultivated lands along river are small in area, and no factories dischg. waste water which could pollute river. River has always much water and purity is superior to that of any other river in Harima dists. Water is comparatively soft, mainly owing to low cont. of Ca ion. Consequently, water of the Chikusa seems to be suitable for an industrial use as well as municipal water supply.—*CA*

Practical Aspects of River Pollution. D. H. PRICE. Eng. and Contract Rec. (Toronto), **67**:18:10 ('56). In paper presented at Inst. of Sewage Purif. (Br.), Apr. '56, description was given of incidents of sudden poln. of surface waters, with resultant death of fish. Cases of cyanide poisoning of fish, unusual case of copper dischg. inorg. source of free ammonia, hydrochloric acid waste contg. org. matter, and cases of lead, tar, and oil poisoning, were given. Natural changes due to development of algal blooms were described. Conclusion reached by author, however, is that rivers are, usually, very stable systems with remarkable capac. for absorbing and rendering harmless toxic substances present.—*PHEA*

The Study of the Pollution of a River and Its Self Purification. Application of a Research Method to the Geer River (Belg.). E. LECLERC; P. BEAUJEAN; & M. R. HEUSE. Bul. Centre Belge Etude et Document. Eaux (Liege), **33**:142 ('56). Principal observa-

(Continued on page 86 P&R)

feco
LIGHTNING
SURFACE WASH BAFFLES
for RAPID SAND FILTERS
Increased velocity of backwash water in cleaning area above expanded sand doubles dirt carrying ability. Directs flow of water to wash troughs and puts all foreign matter in sewer. If filter develops uneven flow or "sand-boils," baffles deflect flow horizontally toward surface of sand in areas where vertical flow is restricted. Creates slight back pressure on filter above sand level, helping to equalize flow. Covers provide surface for precipitation of solids, reducing load on filter. Dirt can be washed off these surfaces into wash troughs.
WRITE FOR CATALOG NO. 5-2
FILTRATION EQUIPMENT CORPORATION
271 HOLLENBECK ST. · ROCHESTER 21, N.Y.

the problem...

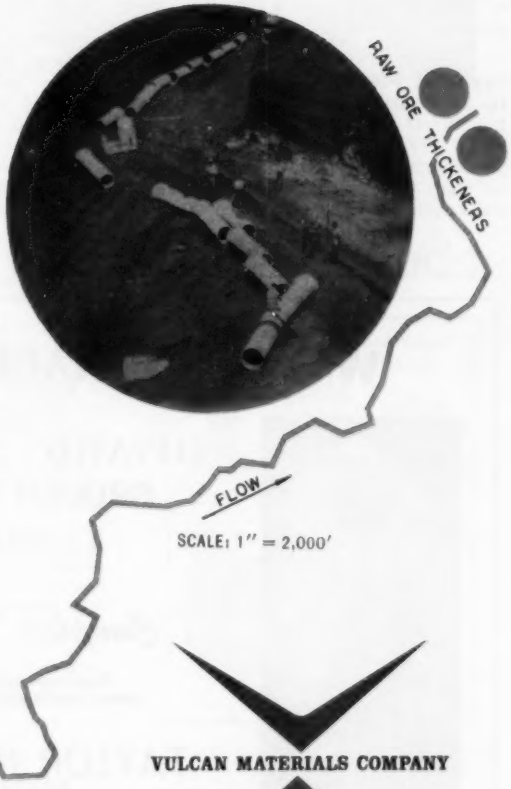
The Problem: To move a mountain of nickel ore down to sea level.

The Project: Mining operation of Freeport Nickel Company (subsidiary of Freeport Sulphur Company) at Moa Bay, Oriente Province, Cuba.

The Engineer: Bedell and Nelson, New Orleans, La.

The Solution: Making a slurry of the ore and moving it by gravity on a 1½ per cent grade through nearly three miles of 24" Cen-Vi-Ro pipe.

The Result: An ore moving system of unparalleled economy.



VULCAN MATERIALS COMPANY

CONCRETE PIPE DIVISION

3030 Peachtree Road, Atlanta, Georgia CEdar 3-7127

(*Continued from page 84 P&R*)

tions which should guide study of river should be based on temp., time, and turbulence. Particular attention should be paid to: [1] Gradient. In theory this controls speed of flow (time). In reality, aberrent profiles of river exist caused by natural or artificial conditions. These should be known. Gradient is important factor in turbulence. [2] Flow. Flow interferes in phenomena of deposition or suspension. It is factor in turbulence, influences equally time of journey, and acts on dilution. [3] Temp. Temp. acts on speed of decantation, rules phenomena of fermentation (function of time) as much as sludge in water, and it influences reoxygenation.—*PHEA*

Travel of Pollution in Sandy Soils and Its Purification En Route. J. K. BAARS. Bul. World Health Organization (Geneva), 16:727 ('57). Problem which is of particular importance to Neth., where water-supply for many large towns is drawn from water underneath the dunes, is extent to which pold. waters are purified in their passage thru sandy soils. This and related problems are discussed in this paper with particular description of some of the exptl. work which has been undertaken. Chem. and bact. investigations of soil were made at different camps in Neth. to det. extent of penetration of poln. in dry and wet soils and also deg of purif. which resulted during passage of pold. waters. Exptl. results are set out in tables. Some of conclusions are that serious poln. of subsoil may be counteracted by self-purifying capacity of soil, provided soil latter is dry and contains sufficient amt. of free oxygen. Under these conditions mineralization may be intense and vigorous adsorption of bacteria by sand particles takes place. If ground water level is high, however, contaminants which have reached ground water may remain practically unchanged for long periods. Artificial rechg. of ground water basin is in action in Leyden and is being put into operation in The Hague and Amsterdam (all Neth.). In this connection expts. described indicate that when mod-

(*Continued on page 88 P&R*)

WATER STORAGE TANKS

ELEVATED
GROUND RESERVOIRS
STANDPIPES

Complete Tank Service

Engineered and Erected According to
AWWA-AWS-FIA-FM and NBFU Specifications

TAYLOR IRON WORKS
MACON, GEORGIA
Serving The Southern States Since 1898

Please Address Inquiries To
Box 218 Macon, Ga. Box 6493 Jacksonville 5, Fla.

AT ELEVEN PLANTS ACROSS THE COUNTRY, Jones receives tank cars of Chlorine, repackages it in cylinders and 1-ton tanks, makes quick deliveries to users in area.

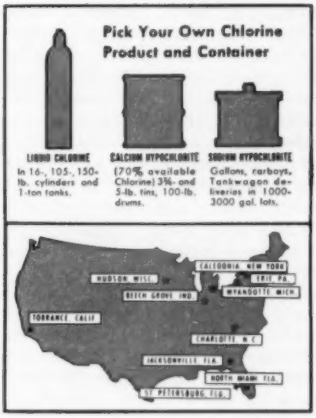
ONE convenient source for all your chlorine needs

Get chlorine products any way you want them, in any amount you need, from just *one* dependable source—Jones Chemicals.

It eliminates hop-scotch buying of liquid chlorine, calcium hypochlorite, or sodium hypochlorite, and enables you to plan your needs and deliveries . . . avoid excess storage. Eleven Jones plants, strategically located across the U.S., stand ready to deliver chlorine products *when you need them.*

Get chlorine in any amount—from 16-lb. cylinders to 1-ton tanks. Jones packages high-purity chlorine in less than carload lots—then lets you pick the size and type of container you need.

Our trained technical staff will be glad to help you with your chlorine problems. Write for information and prices, or contact the Jones plant nearest you.



John Wiley
JONES CHEMICALS, INC.

"A good name in chemicals"

Beech Grove, Ind. Charlotte, N. C. Jacksonville, Fla. St. Petersburg, Fla.
Caledonia, N. Y. Erie, Pa. North Miami, Fla. Torrance, Calif.
Hudson, Wis. Wyandotte, Mich. Warwick, N. Y.

(Continued from page 86 P&R)

erately pold. water is infiltrated into ground water org. matter and bacteria are vigorously adsorbed by sand in upper 10 ft. Intermittent infiltration method of rechg. has particular value. For self-purif. to be effective it is essential that sand should be very fine —effective particle size about 0.15 mm (0.006 in.).—*BH*

Theoretical Bases of Hygienic Standardization in Cases of Simultaneous Pollution of Watercourses With Several Harmful Substances. S. N. CHERKINSKII. Gigiena i Sanit. (Moscow), **22**:8:3 ('57). For substances having similar harmful influences (taste, color, smell, effect on BOD, etc.) guides to deciding cases of mixed poln. are (**I**) max. allowable amt. of each substance should be divided by no. of substances present, or (**II**) sum of concns. of all substances, expressed in % of corresponding max. allowable concn. for each separate substance, should be less than 100%. **Evaluation of the Air in Industrial Premises Polluted With Several Harmful Substances.** A. S. AVER'YANOV. Ibid., 64. Use of method **II** is proposed.—*CA*

Streptococci as an Index of Pollution of Water. LEIGUARDA ET AL. Rev. Obras. Sanit. Nacion (Buenos Aires), **38**:166 ('56). Comparative count was made of streptococci, coliform bacteria, and *Escherichia coli* in 1,000 samples of water of various kinds, including river water, treated surface water, and ground water with or without treatment; results are tabulated. Of 911 samples of treated surface and ground water and untreated ground water: 332 gave positive tests for coliform bacteria and/or streptococci; of these 332 contamd. samples, 83.1% contained coliform bacteria and 45.8% contained streptococci. Only streptococci were found in 56 samples. It is, therefore, recommended that advantages of including test for streptococci in methods for bact. examn. of water should be considered.—*WPA*

Organization of Cooperative State-Industry Stream Studies in Wisconsin. R. H. SCOTT ET AL. Sew. & Ind. Wastes, **29**: 298 ('57). Joint effort by state water poln. control agency and representatives of pulp and paper industry directed towards collection of basic data on stream conditions has resulted in standardized program of testing and evaluation. State supplies necessary field equip., glassware, and reagents; industry provides personnel and laboratory facilities for detn. of temp., pH, DO, and 5-day BOD at sampling stations selected so as to evaluate tot. stream condition. Special surveys of critical reaches of stream include flow gaging by std. USGS procedures and sampling at points throughout stream cross-section with Kemmerer sampler for detn. of BOD, DO, pH, deoxygenation rates, and suspended solids. Special surveys require 3 men in each field crew and 2 lab. workers per crew. —*PHEA*

Determination of Stream Purification Capacity. B. F. LUECK ET AL. Sew. & Ind. Wastes, **29**:1054 ('57). Generalized definition for stream purif. capac. has been proposed. In heavily loaded flowing stream purif. capac. in terms of ultimate BOD satisfied daily per 1,000 cfs/mi will apparently range from 400 to 4,000 lb, depending on temp. and rate of reaction. In heavily loaded impounded waters max. purif. capac. may reach 40,000 lb of ultimate BOD daily per 1,000 cfs/mi. Permissible loading based on oxygen removed can apparently range from about 13 lb of 5-day BOD daily per cfs/ppm of dissolved oxygen removed at water temp. of 24°C to about 20 lb at 11°C. Rate conts. obtained from heavily pold. waters indicate that capac. of purif. per unit time can increase 5-fold in passage of stream thru zone of max. oxygen depletion. Rate consts. are of help in evaluating type of loading and effect of varying resistance to oxidation upon purif. capac. of stream.—*PHEA*

Challenge to Research by Water and Air Pollution Problems. R. W. HESS. Ind. Wastes, **1**:273 ('56). Increasingly greater no. of regulations controlling waste dischg. to water and air are being established. Unfortunately, many of these regulations are not based on scientifically proven facts and do not achieve desired results in economical manner. As result, great amt. of research is needed in sciences of water and air. More research is needed to establish better yardsticks of water and atmospheric qual. to develop production processes which will give min. amts. of wastes, to improve known methods of waste treatment and to develop new anal. techniques. Of particular need is re-

(Continued on page 90 P&R)

Weir plates of Everdur control water flow in Toronto's new Humber plant

These corrosion-resistant Everdur weir plates will handle *50 million gallons* of water every day at the new Humber sewage treatment plant.

Easy fabrication. Everdur weir plates are being joined by arc welding prior to installation.

EVERDUR RESISTS CORROSION. Installations of Everdur sewage-treatment and waterworks equipment in the United States have been in service without replacement for 30 years and longer.

EVERDUR IS TOUGH. Everdur, Anaconda's group of copper-silicon alloys, also possesses high physical strength and resistance to wear and abrasion—so that wrought equipment can be designed with lighter weight.

EVERDUR IS READILY FABRICATED. Everdur alloys are available for hot or cold working, welding, free machining, forging and casting—and can be supplied in plates, sheets, rods, bars, wire, tubes, electrical conduit, and casting ingots.

WRITE FOR PUBLICATION E-11—or for assistance from the Technical Department in selecting the correct material for your equipment. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 6996

EVERDUR® Anaconda's Family of Copper-Silicon Alloys
MADE BY THE AMERICAN BRASS COMPANY

STRONG • WELDABLE • WORKABLE • CORROSION-RESISTANT

(*Continued from page 88 P&R*)

search on wastes from nuclear energy industry. Disposal of radioactive wastes may limit development of this industry. If needs for research are to be met many more projects should be undertaken. Challenges should be met with active interest by industry and research institutions. Although value of this type of research is not as tangible as development of production process, it should, nevertheless, be supported by applying to it highest type of research talent.—*PHEA*

Colorimetric Experiments to Determine Possible Contamination of Water Sources in a Chalk Formation in the River Lyna (or Alle) Pol. K. EISSELE. Gas- u. Wasserfach. (Munich), **98**:84 ('57). Dye uranin was used in 4 different locations to det. possible contamn. of water sources some distance away. Soln. was introduced into possible source of contamn. and time of its appearance at springs and color intensity observed. In several cases unsuspected water flows were detected.

Pollution Survey Sampling of New York Harbor. R. SHAPIRO. Sew. & Ind. Wastes, **28**:1504 ('56). This article discusses period of rapid pop. growth in N.Y.C. metropolitan area and points up production of domestic sewage being dischgd. directly into nearest watercourse for disposal. It

(*Continued on page 92 P&R*)

KNOW THE BENEFITS OF SILICA SOL FOR YOUR PLANT ?

PQ SOLUBLE SILICATES

Trademarks Reg. U.S. Pat. Off.

Your plant may obtain benefits such as these through the use of N-Sol Activated Silica (coagulant aid).

- **improved quality of filter water**
- **wider effective pH range in treatment**
- **increased compaction of sludge**
- **increased equipment capacity**
- **reduced cost of new installation.**

N-Sol is prepared at your plant from N sodium silicate* and a reacting chemical.

Jar tests can help you decide. Ask for samples of N silicate and reactants for test.

*41° Baume (8.9% Na_2O, 28.7% SiO_2)

PHILADELPHIA QUARTZ CO.
1142 Public Ledger Bldg., Philadelphia 6, Pa.

NON-STOP FILTERING

even when backwashing GFC Multi-Cell Filters

There's no time lost when backwashing GFC Multi-Cell Filters. While one cell is being backwashed, the other cells provide: **(a)** Water for backwashing that cell **with or without** the use of storage tanks or surface reservoirs. **(b)** Uninterrupted filtering to maintain a continuous flow to service lines. Other important features include low-cost installation and GFC's patented non-clogging "Multi-Plate" underdrains. Write for bulletins and equipment data.

GENERAL FILTER CO.

WATER PROCESS EQUIPMENT AMES, IOWA

AERATORS • FILTERS • SOFTENERS • CLARIFIERS
FLASH MIXERS • FLOCCULATORS • PNEUMATIC CONTROLS
ROTARY DISTRIBUTORS • SLUDGE SCRAPERS

HAYS

the Quality Line
IN
WATER
SERVICE
PRODUCTS

CORPORATION
STOPS

One of a
complete line of
Water Service
Products

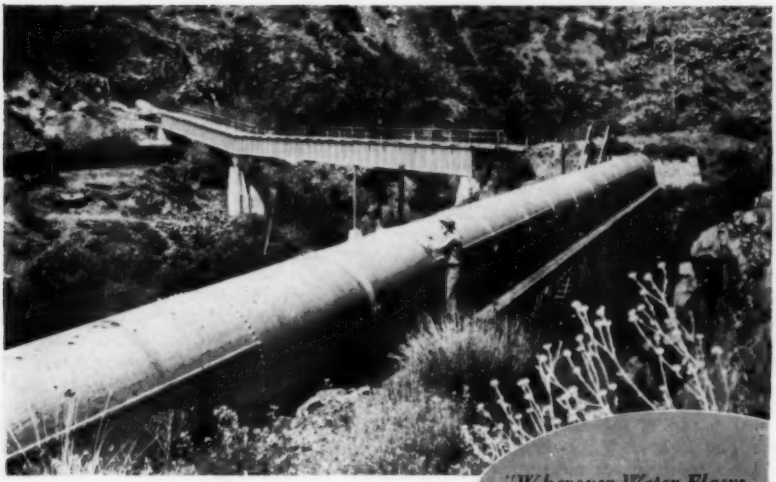
GENERAL PRODUCTS DIVISION
HAYS MFG. CO.
ERIE, PA.

(*Continued from page 90 P&R*)

was pointed out that this was understandable procedure from economic standpoint, particularly when public health hazards from raw sewage were not well understood. Eventually receiving waters became overburdened with putrescentable material and problems were recognized. 1st problem dealt with extent to which N.Y. harbor and adjacent waters were actually pold. and 2nd problem was concerned with tidal and current distr. of polg. load. It was necessary to have extensive poln. and hydrological survey made to ascertain details of problem and background for corrective measures. Investigation of this problem was started by N.Y. Bay Poln. Commn. during '03–'06 period and was carried out by various agencies until present time. Authorities who studied harbor differed in regard to signif. of each of various forces involved, extent of load applied, and amt. and type of treatment required to maint. satisfactory conditions. Description of geography of harbor is given with particular reference to rationality of sampling program. This harbor has unusual geography and tidal pattern that is somewhat different from those familiar to san. engrs. Sampling procedures and time of runs are described, also various areas that are covered with each sampling schedule. Various anal. dents. made on each sample are indicated and procedures for these are enumerated. Various agencies that are interested in this study are mentioned. Local, state, and interstate agencies each have principal objective and each conducts survey different to some extent from that of N.Y.C. Dept. of Public Works.—*PHEA*

Pollution of a Collective Nature in Surface and Subterranean Waters. L'Eau (Paris), **43**:263 ('56). Symposium presented following topics: **I. The Risks of Water Pollution by Products of Radioactivity.** JAMMET. In this report Fr. san. engrs. are appraised of various problems related to radioactivity and its waste products. Characteristics of radioactive substances, cycle of radioactive materials in nature, toxicity of radioactive substances, permissible norms of radioactivity, origin of radioactive poln., struggles against radioactive poln., and methods of monitoring potable water are among topics discussed. **II. The Pollution of Water by Products Using Detergents.** A. LE STRAIT. Prepn. of

(*Continued on page 94 P&R*)



"Wherever Water Flows STEEL PIPES IT BEST"

It's "in very good condition" after 47 years of rugged service

The scene is near Denver. The pipe is steel, 60 in. ID, with ⅜-in. walls.

This big main has been delivering raw water to the city since 1912. under conditions about as tough as you'll find anywhere. The pipe is above ground, exposed to winter temperatures as low as 20 degrees below zero. But, after 47 years, the Water Department reports: "This pipe is in very good condition and is still giving satisfactory service."

With today's vastly improved lining, coating, and wrapping techniques, there is no known limit to the effective service life of large-diameter steel pipe. What's more, because of steel's unequalled combination of great strength and ductility, steel pipe is unharmed by stresses that would damage more brittle materials.

And remember, *every length* of steel pipe is hydrostatically tested in the shop in accordance with AWWA specifications!

You can specify steel fabricated pipe with confidence.

STEEL PLATE FABRICATORS ASSOCIATION

105 West Madison Street
Chicago 2, Illinois

(Continued from page 92 P&R)

emulsifying products, lather products, wetting agents and surface-tension active agents, is described. 10-fold increase in marketed products using such materials has presented many problems in management of sewage systems. **III. The Contamination of the Soil and of Waters by Products Used in Agriculture.** J. KEILLING. In agricultural practice uses of nitrogen in fertilizers, sulfur, copper, and arsenic in plant disease control, and such organic products as insecticides and herbicides has increased cont. in soil of toxic materials which may be carried to water supply systems in runoff waters. **IV. The Pollution of Waters of Several Rivers in Eastern France.** G. NOISETTE. It is shown that waters of several rivers carry increasing mineralized materials as result of variable flow, increasing industrialization, and the geol. nature of region. **V. Pollution of Rivers and Lakes.** P. VIVIER. Using various chem. and plankton measurements, poln. of several rivers and lakes in Fr. is described. —*PHEA*

Treatment of Polluted Water. The Ionomatic Process. Fluid Handling (London), **No. 92**:282 ('57). Ionomatic method for producing clear, colorless, sterile water, which is essential in high-qual. paper mfr., is described. Ionomatic process was designed to treat pold. and other difficult waters by coagulation with silica and aluminium sulfate, sedimentation, and filtration thru rapid open gravity filters. 1st plant of this type was installed at paper mill to treat 3 mgd of pold. river water. Raw water is pumped into dosing channel where aluminoferric is added, and then into concentric reaction tanks. Sodium silicate soln. is used to wt. floc and increase rate of sedimentation. Sludge is periodically drawn off from bottom of conical reaction tanks and clarified water overflows and is fed to gravity filters. —*WPA*

Purification of Waste Waters From Fish Ponds. G. SCHULZ. Wasserwirtsch. Wassertech. (Berlin), **6**:314 ('56). Waste waters from fish-processing industries have high cont. of fat and protein. This fat-protein emulsion is decompd. by pptn. with 2.5 g/l Al_2O_3, 2.5 g/l lime, and 100 mg/l $FeCl_3$. Fats are collected in separator. Chlorination before this treatment is advised.—*PHEA*

Brackish Water as a Recipient of Pulp Mill Waste Water. L. BRUNEAU. Svensk Papperstidn. (Stockholm), **59**:465 ('56). Polg. effect on stratified brackish water was studied in vicinity of pulp mills along N. coast of Swed. Dissolved org. material follows surface water; at mills located at open coast it is quickly consumed in summer. In winter, when this consumption is slow owing to low temp. and moderate wind turbulence, pold. water (**I**) is spread over great areas as thin stratum under ice. In closed regions, especially fiords, poln. is quite serious, even at greater depths. Waste-water dischg. should be made so that mixing is obtained with largest possible vol. of sea water without **I** reaching deep water where it is blocked from air. Fibers deposit generally on bottom close to point of dischg.; in shallow water they may be transported long distances. There are no indications of direct influence on Baltic herring fishing, but secondary poln. like fungi, fibers, and plankton (after plankton plague) may damage nets. Migratory fishes are influenced mainly at estuaries by **I** which is toxic or low in O. Movements of deep waters will be investigated.—*PHEA*

Lime Treatment of Lake Reduces Acid Mine Waste Pollution. V. W. COLE. Ind. Wastes, **2**:100 ('57). Acid drainage of sulfuritic waste materials from coal veins in different types of coal mines sometimes results in damage to streams and lakes. 1 example of such poln. of lake, L. Alma in S.E. Ohio near city of Wellston, is presented. This lake is 72.5 acres in area, avgs. 9.6 ft deep, and has 9,050 ft of shoreline. Poln. was evidenced by decline in fish pop. and later by reduction in alk. reserve of water. 1st attempt to counteract acid poln. by installation of filter of 100 tons of crushed limestone in lake's main feeder stream was not effective. Since then ('51) direct application of hydrated lime by 2 different methods has produced excellent and economical results. Fish pop. has increased and several new aquatic plants and algae have been observed. Tot. cost of lime used was $80, about 35¢/acre/yr. Even adding labor cost of applying lime, 37¢/acre/yr, still gave inexpensive results for treating this particular lake. Other lakes receiving acid mine drainage would present different problems but it

(Continued on page 96 P&R)

100,000th FW Water Meter!

It took 65 years to do it, but the Fort Worth Water Dept. today put into service its 100,000th water meter.

The 200,000th is expected in about 21 more years.

The gold-finished 100,000th meter was installed at the new home of Mr. and Mrs. Larry Cheeves at 3513 Wosley Dr., a new section of South Hills.

Mr. Cheeves, an engineer at Convair, moved here with his wife three months ago from Toledo. They've been married two years.

Mayor Tom McCann used a gold-finished key to turn on the water at ceremonies this morning.

The lucky owners get a month's water bill paid—that's especially welcome, since Mr. Cheeves has to put in the lawn at the new home.

The city went into the water business in 1892 and started meter service in 1894. Population forecasts predict there'll be twice as many people in Fort Worth by 1980 as there are today—so twice as many meters will probably be installed by then.

reproduced from the front page of the Fort Worth Press

FORT WORTH

Installs its 100,000th water meter . . . a

Calmet

A landmark in the life of a booming Texas City . . . and an occasion which brings recognition of the vital services rendered over the years by the Fort Worth Water Department, under the able direction of Uel Stephens and his associates.

We at Calmet Meter are happy to have shared in this great municipality's growth, as we have in hundreds of others throughout the nation.

WORTHINGTON

CALMET METER DIVISION

2301 SO. MAIN
FORT WORTH, TEXAS

(*Continued from page 94 P&R*)

is believed that procedure used at L. Alma could be successfully applied to other lakes with similar characteristics.—*PHEA*

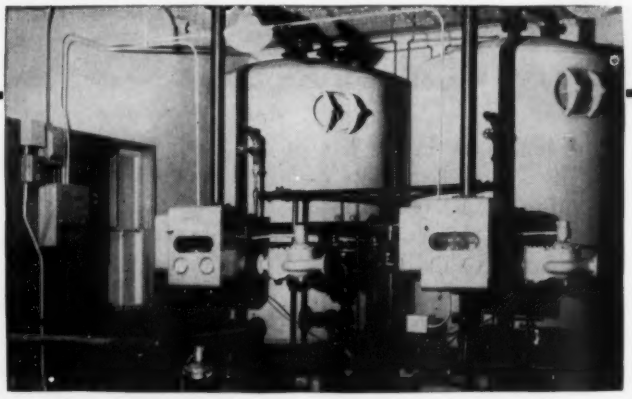
Pollution of Drinking Water by Waste Liquor From Starch Factory. T. AKIYAMA. Yakugaku Kenkyu (Jap.), **28**:13 ('56). Poln. of drinking water from well by starch waste liquor, resulting in white turbidity and brown ppt. was due to increase of Fe in water. Experimentally prepd. waste liquor contg. only sol. components of potato (**I**) and that contg. starch grains (**II**) behave differently. **I** stabilizes at around pH 8.5 and does not dissolve out Fe, but **II**, stabilizing at around pH 4.0, dissolves out large amt. of Fe, amt. being in proportion to concn. and increasing with decrease of pH. pH of pold. water was around 4.0 and contained large amt. of starch grains from waste liquor. Max. amt. of Fe found in such water was 46 ppm. Attention is drawn to fact that poln. of drinking water by starch waste liquor takes form of increased amt. of Fe.—*CA*

Influence and Importance of Daily Weather Conditions in the Supply of Chloride, Sulfate, and Other Ions to Fresh Waters From Atmospheric Pollution. E. GORHAM. Phil. Trans. Roy. Soc. London (London), **B241**:147-78 ('58). Local weather conditions play large part in detg. atmospheric supply of ions to natural waters in Lake Dist. of Eng. Much of sulfate is due to poln. of atm. Sea spray is chief source of Na and Cl. Net loss of rain acids is evident in all soil waters; latter are relatively rich in K derived from decaying vegetation.—*CA*

GROUND WATER

Reconnaissance of the Ground-Water Resources of Chippewa County, Michigan. K. E. VANLIER & M. DEUTSCH. Mich. Dept. Conservation, Geol. Survey Div., Progress Rept. No. **17**:1 ('58). Chem. anals. of 65 waters are given. Most are moderately hard Ca-Mg bicarbonate waters; 8 are high in chloride.—*CA*

(*Continued on page 98 P&R*)



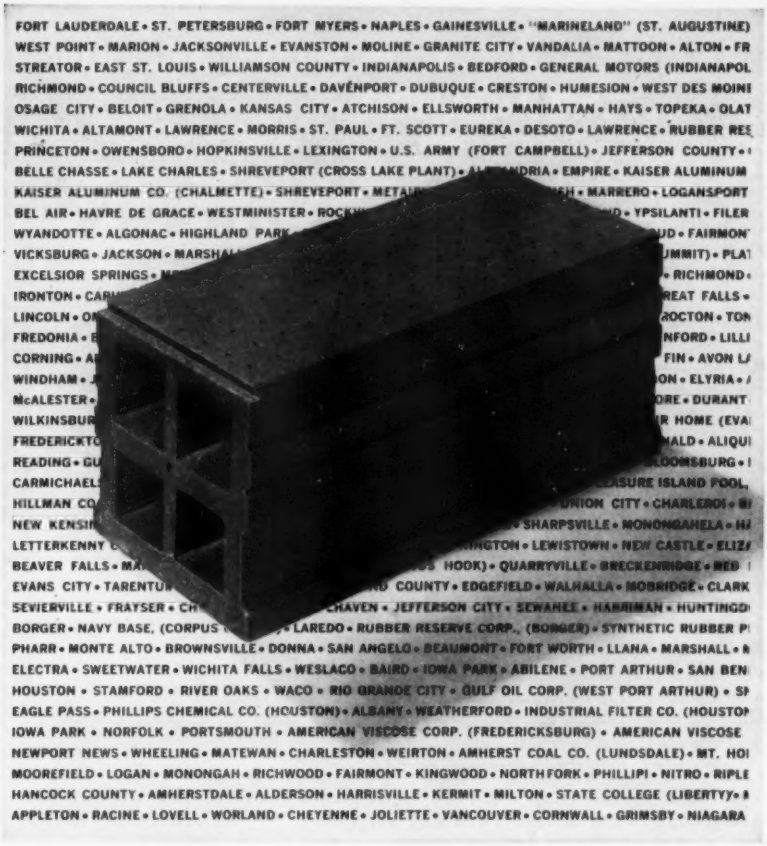
Iron and Manganese Removal Plus Water Softening . . .
Automatically by Ion-Exchange using Invercarb C-110

Low in cost—efficient in operation. Send for Particulars.

H&T SERVICE

HUNGERFORD & TERRY, INC.

CLAYTON 5, NEW JERSEY


FORT LAUDERDALE • ST. PETERSBURG • FORT MYERS • NAPLES • GAINESVILLE • "MARINELAND" (ST. AUGUSTINE)
WEST POINT • MARION • JACKSONVILLE • EVANSTON • MOLINE • GRANITE CITY • VANDALIA • MATTOON • ALTON • FR
STREATOR • EAST ST. LOUIS • WILLIAMSON COUNTY • INDIANAPOLIS • BEDFORD • GENERAL MOTORS (INDIANAPOL
RICHMOND • COUNCIL BLUFFS • CENTERVILLE • DAVENPORT • DUBUQUE • CRESTON • HUMESION • WEST DES MOINI
OSAGE CITY • BELOIT • GRENOLA • KANSAS CITY • ATCHISON • ELLSWORTH • MANHATTAN • HAYS • TOPEKA • OLAT
WICHITA • ALTAMONT • LAWRENCE • MORRIS • ST. PAUL • FT. SCOTT • EUREKA • DESOTO • LAWRENCE • RUBBER RES
PRINCETON • OWENSBORO • HOPKINSVILLE • LEXINGTON • U.S. ARMY (FORT CAMPBELL) • JEFFERSON COUNTY •
BELLE CHASSE • LAKE CHARLES • SHREVEPORT (CROSS LAKE PLANT) •
KAISER ALUMINUM CO. (CHALMETTE) • SHREVEPORT •
BEL AIR • HAVRE DE GRACE • WESTMINISTER •
WYANDOTTE • ALGONAC • HIGHLAND PARK •
VICKSBURG • JACKSON •
EXCELSIOR SPRINGS •
IRONTON •
LINCOLN •
FREDONIA •
CORNING •
WINDHAM •
McALESTER •
WILKINSBUR
FREDERICKTO
READING • GU
CARMICHAEL
HILLMAN CO
NEW KENSI
LETTERKENNY
BEAVER FALLS • MA
EVANS CITY • TARENTU
SEVIERVILLE • FRAYSER •
BORGER • NAVY BASE, (CORPUS
PHARR • MONTE ALTO • BROWNSVILLE • DONNA • SAN ANGELO • BEAUMONT • FORT WORTH • LLANA • MARSHALL •
ELECTRA • SWEETWATER • WICHITA FALLS • WESLACO • BAIRD • IOWA PARK • ABILENE • PORT ARTHUR • SAN BEN
HOUSTON • STAMFORD • RIVER OAKS • WACO • RIO GRANDE CITY • GULF OIL CORP. (WEST PORT ARTHUR) • SP
EAGLE PASS • PHILLIPS CHEMICAL CO. (HOUSTON) • ALBANY • WEATHERFORD • INDUSTRIAL FILTER CO. (HOUSTO
IOWA PARK • NORFOLK • PORTSMOUTH • AMERICAN VISCOSE CORP. (FREDERICKSBURG) • AMERICAN VISCOSE
NEWPORT NEWS • WHEELING • MATEWAN • CHARLESTON • WEIRTON • AMHERST COAL CO. (LUNDSDALE) • MT. HO
MOOREFIELD • LOGAN • MONONGAH • RICHWOOD • FAIRMONT • KINGWOOD • NORTH FORK • PHILLIPI • NITRO • RIPLE
HANCOCK COUNTY • AMHERSTDALE • ALDERSON • HARRISVILLE • KERMIT • MILTON • STATE COLLEGE (LIBERTY) •
APPLETON • RACINE • LOVELL • WORLAND • CHEYENNE • JOLIETTE • VANCOUVER • CORNWALL • GRIMSBY • NIAGARA

These 464 plants* know . . .

How to get to the bottom of backwash problems

The best way is to install Leopold Glazed Tile Filter Bottoms, just as all these plants have done.

Like them, you'll find Leopold Bottoms successfully meet all underdrain requirements. The individual Leopold blocks can't corrode or absorb water . . . are acid and alkali resistant . . . are not subject to tuberculation . . . and provide equal filtration and uniform wash distribution. In addition, because Leopold Bottoms won't wear out and assure minimum media maintenance, they are the most economical in the long run.

We'll be glad to supply facts and figures without obligation.

**Including over 100 rehabilitation projects*

F. B. LEOPOLD CO., INC.
ZELIENOPLE, PA.

Exclusive Canadian Representative: W. J. Westaway, Ltd., Hamilton, Ont.

Leopold

(Continued from page 96 P&R)

Ground Water in the Poverty Bay Flats. T. L. G. TAYLOR. New Zealand J. Sci. Technol. (Wellington), **38**:763 ('57). In Poverty Bay Flats in N. Island, N.Z., there are 3 main groups of water-bearing sediments, all of which will yield water in sufficient quant. for domestic and general agricultural purposes. Only 2, beach sands and shallow gravels, will yield water of suitable qual. for irrig. Water from gravels deeper than 100 ft is so corrosive that well pipes would have to be replaced frequently and its use would therefore probably be uneconomic. For industrial purposes in borough of Gisborne beach sands provide adequate supply of water.—*WPA*

Public and Industrial Ground Water Supplies of the Roanoke-Salem District, Virginia. B. F. LATTA. Bul. Va. Div. Geol., **69** ('56). Chem. qual. of ground waters in Roanoke-Salem dist., Va., was detd. Most of samples examd. were slightly hard to hard bicarbonate waters, but 2 were very hard sulfate waters contg. more than 1,000 ppm sulfate. Only 4 of 15 samples contd. more than 0.1 ppm iron. Except for their hardness, most of waters examd. are satisfactory for municipal water supply, but many would require treatment before they could be used for certain industrial purposes.—*WPA*

Underground Water Investigation at Yûbetsu, Kitami [Jap.]. M. ITO & T. OHARA. Hokkaido Chikashigen Chosasho Hokoku, **15**:9 ('56). Several water-bearing strata are developed in underground of this district—that is, 3–10 m, 15–30 m, and 80 m below the earth surface, resp. Chem. compn. of underground water is given. Distribution of iron and bicarbonate ions and geological structure are correlated.—*CA*

Water Supplies of the Fezzan, the South Libyan Desert, and the Mountain Land of Tibesti. H. WEIS. Gas- u. Wasserfach. (Ger.), **97**:929 ('56). Acct. is given of formation, geology, and hydrology of district of Fezzan, south Libyan desert, and mountain land of Tibesti, with special reference to ground water conditions in oasis-rich district of Fezzan.—*WPA*

HEALTH AND HYGIENE

Swimming and Infantile Paralysis. F. VAN DEN BOSSCHE. Arch. belges med. sociale, hyg., med. travail at med. legale (Brussels), **14**:363 ('56). 33 (3.7%) out of 874 poliomyelitis patients during '55 epidemic in Belg. had swum during 14 days prior to onset of disease. Only 1 case occurred among 900–2,800 daily swimmers in Belg. swimming clubs.—*PHEA*

Bathing and Water Supply. Stadtehygiene (W. Ger.), **7**:269 ('56). At the 6th congress of Assn. of German Health Officials held in Lubeck, W. Ger., Jun. 5–6, '56, following were among papers presented. **I. Problems of Open-Air and Indoor Baths.** PREUNER. Authors deals with requirements of indoor pools, describing poln. contributed by bathers and its removal by coagulation and disinfection by hypochlorite. Planning of establishment and precautions in the use of chlorine are discussed. In open-air baths sepn. into sections for swimmers, nonswimmers, and divers is important. Effects of flow-through and exposure to sun are considered. Such pools are generally made too small. Surroundings of both open-air and indoor pools are discussed. Infection by viruses is best prevented by breakpoint chlorination. **II. Technical-Hygienic Problems in Open-Air and Indoor Baths.** JUNG. Large assemblies of people are always dangerous and pools should not be too large. For open-air pools it is calcd. that on hot days 7% of the population will use pool. Design of surroundings and washing places is considered. Separate sections should be separately operated because chlorine demand of nonswimmer bath is high. Details are given of amt. of water, ventilation, design of building, and suitable materials, for indoor establishments. **IV. Bathing Hygiene and Modern Living Conditions.** LENTZE. Author gives warning against overestimating importance of bacterially polluted bathing water as source of disease. More important is conveyance of infection by food and greatest risk lies in the washing of vessels in pold. water. **V. Central Supply of Water.** KRUSE. Author discusses cost of works, extent of protective areas for intakes, protection of wells against flood water, methods of treatment, and permissible conts. of poisonous elements.—*WPA*

only ONE PUSH makes it PERMANENT...

AMERICAN

Fastite® JOINT***

CAST IRON PIPE

Insert the single joint component—an exclusive dual-density, **double sealing** ★★ rubber gasket . . . lubricate the spigot . . . push pipe together . . . and you have a **permanent** bottle-tight joint.

That's American Fastite® Joint Cast Iron Pipe—American's new favorite for fast, simple installation and long service life.

American Fastite® Joint, an all-weather-laying joint, offers many special advantages for water, sewage and other liquid service.

Get the facts about American Fastite® and **compare** before you buy. Call your nearby American Cast Iron Pipe Company representative now.

*Patent applied for. Underwriters' Laboratories, Inc., approved.

AMERICAN

CAST IRON PIPE CO.

BIRMINGHAM ALABAMA

SALES OFFICES

New York City • Dallas
Chicago • Kansas City
San Francisco • Denver
Pittsburgh • Orlando
Minneapolis • Cleveland
Birmingham

(*Continued from page 54 P&R*)

be "a tax free method of advertising the companies."

The engineering front, by the way, is no longer no man's land. As a result of printing a "Job Qualification Form" in the February issue of *Willing Water,* AWWA now has on file the resumes of a number of well qualified engineers, young and old, interested in employment or better employment in the water supply field.

Not to be electronicized into obsolescence quite yet (see May P&R p. 38), the meter reader is fighting science with science at Monroe, N.C., where he makes his rounds with a walkie-talkie strapped to his back and reports his readings directly to a billing clerk, who enters the data on a visual card file and computes the bill while the reader goes on to the next meter. Much as we admire the spirit of the thing, we wonder if the walkie-talkie isn't heavier than the meter book and what the billing clerk does while the meter reader is making his peace with Fido. Meanwhile, at the Western New York Water Conference in mid-March, one of the electronic devices for automatic reading over a telephone circuit was described by its inventor and patent holder, Curtis M. Cooper, of Binghamton, N.Y., who estimated that his system could read, post, and bill approximately 2,000 meters in one night. God help the meter reader on a night like this!

Marsden C. Smith has retired as chief water engineer for the Dept. of Public Utilities, Richmond, Va., after 44 years with the department. His successor is Ray A. Jackson, chief of design for the department since 1955. Mr. Smith, holder of a number of patents for treatment equipment, has long been active in AWWA committee work and is the author of numerous JOURNAL articles.

A little diversion could have lightened the water customer's burden last April if an income tax angle investigated by the borough attorney at Florham Park, N.J., had worked out, but, instead, his report to the council made it all too clear that any diversion merely increases the load. The diversion involved, of course, was one of water department revenues into the borough's general fund, which led informed residents to ask why they should not take all—or, at least, part—of their water bills as income tax deductions in the same way as they took other local taxes. The answer—that "water charges are a charge for services"—left no room for doubt as to the wisdom of calling a tax a tax, keeping a water rate a water rate, and restricting diversion to entertainment.

To get high fast, just add water! That was the word from Pan Am in New York and ACS in Boston last month—and we have an idea the combination could be ideal.

From Pan American Airways headquarters the story was one of adding water by injection into the engines of its Boeing 707 jets at takeoff, thereby increasing thrust sufficiently to raise gross takeoff weight by 10–15 per cent. The boost in thrust supplied by 800 gal (6,670 lb) of water can increase allowable gross weight for a 707 taking off at Idlewild's 10,000-ft runway from 20,000 lb on a 60°F day to more than 35,000 lb on an 85°F day, meaning either a greater payload or extra fuel

(*Continued on page 102 P&R*)

WATER PRESSURE CONTROLLED

G-A *Cushioned* Water Pressure Reducing Valve

Like the elephant, water pressure can be big trouble if not controlled. That's what the Golden-Anderson Pressure Reducing Valve does. This sensitive valve always delivers water at the same predetermined pressure . . . regardless of upstream variance. No need to fear water line damage from high initial pressures with this Golden-Anderson Valve on the job.

Write for Bulletin W-3A

GOLDEN ANDERSON *Valve Specialty Company*

1221 RIDGE AVENUE, PITTSBURGH 33, PA.

Designers and Manufacturers of VALVES FOR AUTOMATION

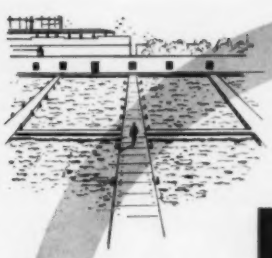
(Continued from page 100 P&R)

to avoid an expensive refueling stop on route.

In jet engines, the water is used, not for cooling as in piston engines, but to add mass to the exhaust gases, thereby increasing the propulsion force of the engine. As 10 ppm dissolved solids are the maximum tolerated in the water used, Pan Am has entered the water treatment field, installing two-bed ion-exchange systems at its Idlewild and Azores hangars. The systems, designed by Penfield Mfg. Co., Meriden, Conn., and built by Rohm & Haas Co., Philadelphia, are both self-operating, water being drawn through them as needed directly into a tank truck. To ascertain that each load is properly treated, a conductivity meter check is made, and the treated water, with its solids content cut usually to 1.5 ppm, is handled strictly in plastic from treatment plant to plane (see cut). Given a shot of water at inlet or diffuser, or both, the jets climb to 400 ft in less than 2 min in what is called a wet takeoff.

At the ACS meeting in Boston, on the other hand, the altitude was rather more subjective and probably could be reached even more quickly without water, but "just add water" was the intent as two chemists introduced the possibility of a synthetic, hangover-proof, instant whisky. Having identified and measured the various volatile

(Continued on page 104 P&R)



HTH

complete chlorination from source to faucet

Use HTH Granular for quick, direct, chlorine action at every point of the water-supply system: reservoirs, pumping stations, filters, mains . . . to say nothing of tanks, standpipes, wells, ponds, etc.

Dry, non-dusty, and easy-to-use . . . convenient, effective and economical . . . HTH Granular, with 70% available chlorine, means an end to problems of bacteria, algae, fungi and odors.

Olin Mathieson will gladly send you complete information about the many uses of HTH for the complete chlorination of water. Just write. Or check your supply house soon.

HTH GRANULAR is available in 100-lb. drums and in cases of nine 5-lb. cans.

HTH 4907

OLIN MATHIESON CHEMICAL CORPORATION
CHEMICALS DIVISION • BALTIMORE 3, MD.

® HTH is a trademark

Faster LOCATING!
LOWER SERVICE COSTS
with the improved AQUA VALVE BOX LOCATOR!

Your Name In Gold FREE!
$29.50 F.O.B. Cincinnati, Ohio
STOCK this useful tool for every service CAR and CALL •
Speed Locating • Keep Customers Happy

- NO WIRES, BATTERIES or SWITCHES—simple, powerful magnetic action, factory adjusted to YOUR geographical location assures unfailing results!
- NO NEEDLE SPINNING—exclusive electric braking action saves you time!
- NO STOOPING—easy top-view reading!
- RUGGED—compact, accurate, convenient!
- GUARANTEED—to function regardless of weather, surface or ground cover!
- NATION'S MOST WIDELY USED LOCATOR!
- 15-DAY FREE TRIAL—No money! No obligation! You be the judge!

ORDER NOW - Wire or Call Kirby 1-4200 collect
AQUA SURVEY & INSTRUMENT CO.
2028 Leslie Ave., Cincinnati 12, Ohio

FIND LEAKS FASTER
WITH THE AQUA SURVEY AQUAPHONE

Only $4.50 EACH 6 for $25.00 ORDER NOW

RUGGED! SENSITIVE!
Super-sensitive scientific pre-tuned diaphragm without mechanical connection between diaphragm and probe, makes this the industry's most durable instrument. Genuine molded Bakelite case. Unconditionally guaranteed against mechanical failure for life of instrument! Order one for every service man. 2 Ft. probe Extension $2.25.
AQUA SURVEY & INSTRUMENT CO.
2028 Leslie Ave., Cincinnati 12, Ohio

(Continued from page 102 P&R)

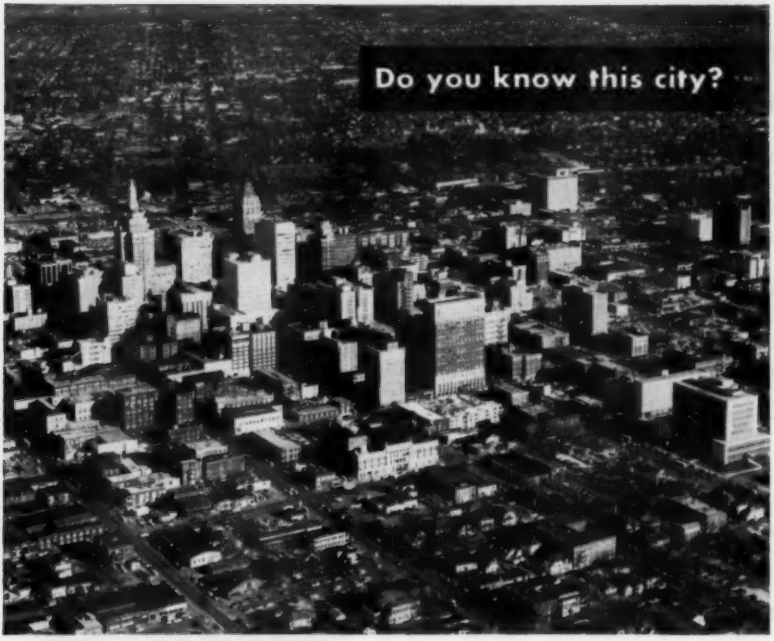
chemicals which distinguish the different types of alcoholic beverages, Robert Carroll, a consultant from Greenwich, Conn., and Lawrence C. O'Brien, of the Perkin-Elmer Corp., Norwalk, Conn., were able to point to Scotch as the least hangoverful of whiskies and to vodka and gin as even clearer in the head than Scotch. Just how they propose to extract the flavor, aroma, body, and other qualities of good liquor and then recombine them for quick takeoff, rapid climb, smooth flight, and happy landing was not revealed, but we have already put our experience at their disposal if they require assistance—with the most important ingredient, of course.

All of which reminds us to observe that, in flying, whisky is as effective in breaking the sound barrier as are jet engines.

Howard S. Morse has retired as chairman of the board of Indianapolis (Ind.) Water Co., after more than 34 years with the utility. He will continue as a director. Morse joined the company as manager in 1925 and was elected vice-president in 1938 and executive vice-president in 1949. He retired in 1951 but returned to the company as president in 1953. In 1956 he became board chairman. Water service facilities at Indianapolis nearly doubled during Morse's career, as did the number of customers. His major accomplishments include the planning and construction of Geist and Morse reservoirs, the latter named in his honor.

The company also announced the election of Lewis S. Finch, vice-president and chief engineer, to the board. AWWA President Finch fills a vacancy on the board left by the death of Howard J. Lacy.

(Continued on page 106 P&R)



DE LAVAL *water works pumps serve the citizens of...*

Tulsa...In the heart of the oil country, De Laval centrifugal pumps work 'round-the-clock to meet the fast-growing needs of this dynamic community. In other major cities throughout the country, the De Laval name is synonymous with dependable, efficient water works equipment.

Today, in fact, the great majority of American cities use De Laval centrifugal pumps. Their design and manufacture are the result of more than 57 years of experience. Units ranging up to 100 million gallons per day are available to meet all water works requirements.

Write for your copies of De Laval Bulletins 1004 and 1005 giving data on these pumps

DE LAVAL *Centrifugal Pumps*

DE LAVAL STEAM TURBINE COMPANY
822 Nottingham Way, Trenton 2, New Jersey

DL-407A

(Continued from page 104 P&R)

As a matter of fact

● Minnesota has more surface water within its boundaries than any other state, including 11,007 lakes of 25 acres or more, yet 95 per cent of all Minnesota communities of 25,000 or less obtain their water supplies from underground sources.

● Backyard swimming pools in the US are increasing at a rate of 30,000–40,000 per year.

● At Sterling, Colo., city hall records revealed that the local sugar factory in October 1908 used 19,500 gal of water at a cost of $7.32 compared to an october 1958 use of 10,986,000 gal at a cost of $732.

● A camel can drink 25 gal of water in 30 min, but does not store it in his hump.

● The Intermountain Section area comprises approximately 7.5 per cent of the area of the US (first 48 states, that is) and 0.8 per cent of its population, density being 5.35 persons per square mile. Included in the area are approximately 500 water systems.

● Recreation boats in the US totaled 15,000 in 1904. By 1947 the number had grown to 2,440,000. In 1958 it reached 7,330,000.

● During the academic year 1957–58, with earned degrees up 7.5 per cent over the previous year, science degrees registered a gain of 9.5 per cent and engineering degrees, 13.1 per cent.

● For emergency use, OCDM estimates personal water requirements at 7 gpcd. As a minimum space ship supply, University of California scientists have estimated 10–15 gpcd, noting that 1 gal per capita per week is enough for drinking.

● The total capital investment values of water supply and treatment facilities in the United States, according to preliminary estimates by the Water & Sewerage Utilities Div. of BDSA, is just short of $125 billion, of which slightly more than $30 billion represents water utility investments. The balance covers power, industrial water supply, rural domestic systems, irrigation, navigation, and flood control facilities.

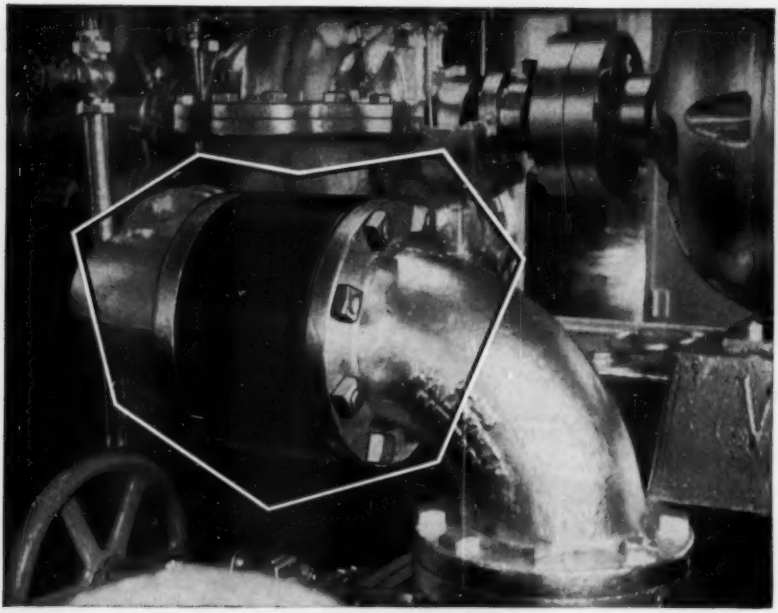
● Fort Worth, Tex., installed its 100,000th meter in May.

● Average per capita water intake per day is 4½ lb, compared to only 2¾ lb of food. Both these are considerably lighter than air intake, however, as that —at any rate, in the metropolitan areas —totals 30 lb per day.

● The population of New York City has dropped approximately 100,000 since 1950, reflecting the trend toward suburbia, while the population of the state has increased by approximately 2,050,000. Estimates for Jul. 1 indicate a total state population of 16,775,000, more than half living outside New York City.

● More than 14.9 bil gal of water was supplied to approximately 600,000 residents of suburban Montgomery and Prince Georges counties in Maryland through 1,575 mi of water mains at a per capita cost of 2 cents per day by the Washington Suburban Sanitary Commission during 1958. That figures out to a per capita use of 68 gpd and a price of 1 cent for 34 gal. Growth in customers during the year totaled 5,817.

(Continued on page 110 P&R)



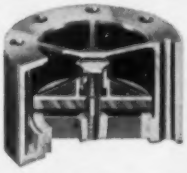
ELIMINATE BACK-DROP, SURGE AND HAMMER

When CPV silent, non-slam check valves are installed on the discharge of centrifugal pumps, the whole system is protected against waste and harmful surges. The need for expensive air cushions and other anti-hammer devices is eliminated.

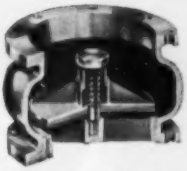
Spring-actuated, CPV check valves close automatically as soon as flow ceases. Back travel, which can be so damaging, is not required for closing.

Users report CPV valves easy to install and require no maintenance. Unique design includes bearing guides on both sides of disc and a full flow area in excess of pipe area. The valve operates in any position.

For complete specifications and prices write Combination Pump Valve Company, 853 Preston Street, Philadelphia 4, Pa.



STYLE "G"—2 to 10"



STYLE "GB"—6" and up

CPV SILENT NON-SLAM CHECK VALVES

Reader's
Oh, what will you do without water?
America is using 167 million gallons of water a minute! Demand increases by the hour. By the time today's toddlers are grown, we'll need twice as much water. Where will it all come from? Will you have enough? You'll find the answer below . . .
Now, what can you do about water?
This free booklet, "WATER—make sure you'll always have plenty," tells how to learn if you're running short, what to do if you are. Write Cast Iron Pipe Research Assn., Prudential Plaza, Chicago 1, Ill.
WATER
Printed in your interest by the makers of America's greatest water carrier . . .
CAST IRON PIPE

New Ad Campaign in Reader's Digest Dramatizes America's Water Problem

Cast Iron Pipe Research Association promotes better understanding of water supply and distribution problems

Offers Informative Booklet for Step-by-Step Action at the Local Level

Here's help for you and everyone else directly concerned with the supply, treatment and distribution of water—help that will acquaint the people in your town with the vital importance of this growing problem.

On the opposite page you see the first in a series of advertisements, this one appearing in February *Reader's Digest.* Placed by the Cast Iron Pipe Research Association, these striking advertisements point out to Mr. and Mrs. America how much we depend on a good water system and why we can no longer take it for granted.

Similar advertising will appear regularly this year in *U. S. News & World Report, Nation's Business, Better Homes & Gardens, American Home* and *Sunset* magazines to carry this public service message to millions of community leaders and homeowners.

Free Local Plan-of-Action Booklet

These ads offer a free booklet telling about the water problem. It shows how responsible citizens can acquaint themselves with the needs of their community. It also gives a step-by-step outline of action, telling how they can help their officials extend and improve the local water system through more adequate rate structures or financing.

We'll be happy to send you a free copy of this new booklet. Write to Thos. Wolfe, Managing Director, Cast Iron Pipe Research Association, 3440 Prudential Plaza, Chicago 1, Ill.

Three reasons why cast iron pipe is America's greatest water carrier:

1. More miles of underground cast iron water mains are now in use than of all other kinds of pipe combined.

2. More miles of cast iron water mains are now being purchased and laid than of any other kind of pipe.

3. Impartial surveys prove that today's water utility officials and consulting engineers prefer cast iron pipe for underground water distribution by an overwhelming majority.

CAST IRON PIPE

THE MARK OF THE 100-YEAR PIPE

(Continued from page 106 P&R)

A pineapple with 100,000 gal of juice saluted Hawaii's statehood last March as the Hawaiian Pineapple Co. hung a special banner on its water tank (see cut), which has been a Honolulu landmark since it was erected in 1927 by the Chicago Bridge & Iron Co.

Water's powers seem as unpredictable as they are limitless. What water utilities serve as a necessary but not very exciting commodity of everyday life, commerce, and industry, continually surprises us in the variety of its unusual applications. Thus, between mid-April and mid-May, we found it featured in no less than three new guises—as an inebriant, a panacea, and a vehicle of prayer.

Revealing its inebriating effects were two British doctors reporting on nine of their patients who were "compulsive water drinkers," consuming as much as 15 qt (Imp.)—more than 22 fifths—per day. Result of the excessive intake is dilution of the blood, causing the same kind of intoxication as that from drinking too much alcohol. And, actually, the underlying cause of the uncontrollable thirst involved is the same in both "hydrolics" and alcoholics—a deep-seated emotional disturbance. The patients described became addicted usually after the age of 50, and in their addiction displayed all the ingenuity of experienced alcoholics in sneaking their drinks—even resorting to snorts from handy vases. What disturbs us about their cure is not the fact that water utilities will be losing their best customers—after all the "stuff" adds up to less than a penny a day—but the thought of putting them on the whisky wagon at almost $70 a day.

And speaking of cures, the panacean powers of water were reported from Lundazi, Northern Rhodesia, where a new African sect, the Zion Church of Christ, is based on the belief that water and faith will cure any disease, "from pneumonia to toothache." It was Tumbuka tribesman Levi Zimba, leader of the sect, who was cured of pneumonia, and among his 100 followers in Rhodesia and many more in Nyassaland every other kind of disease has yielded to the water treatment. But this method of drinking-thinking your troubles away dates back at least to 1945, when a local man, named Twodays, came back from the mines in Johannesburg and "cured many people by giving them water to drink."

It was water and faith, too, that the Rev. Franklin Loehr of the Religious

(Continued on page 112 P&R)

New!

TIME-$AVING COMBINATION LEAK DETECTOR-PIPE LOCATOR

THE M-SCOPE MASTER
Electronic Witch Combination

You're looking at the much-talked-about **NEW** M-Scope . . . the only dual-purpose that **detects leaks and locates pipe.** Its rugged, highly efficient electronic circuit, plus **ease** of use and portability, make this instrument one of the most welcome contributions to the water works industry.

Quick Facts

LOCATING A LEAK AT THE VALVE

FINDING A LEAK UNDER PAVEMENT

ONE MAN OPERATION

LOCATING A SERVICE

For greatest convenience and reliability, the M-Scope MASTER is equipped with a **built-in battery tester** for instant checking of battery condition in the field or **elsewhere.**

WRITE TODAY FOR SPECIFICATIONS AND PRICE!

PIPE LINE EQUIPMENT
JOSEPH G. POLLARD CO., INC.
PIPE LINE EQUIPMENT
PIPE LINE EQUIPMENT

Place your next order with POLLARD

It's from POLLARD . . . It's the Best in Pipe Line Equipment

NEW HYDE PARK • NEW YORK

Branch Offices: 964 Peoples Gas Building, Chicago, Illinois
333 Candler Building, Atlanta, Georgia

(*Continued from page 110 P&R*)

Research Foundation, Los Angeles, combined in the experiments he reports in his new book, *The Power of Prayer on Plants*. In conducting their first experiment, Loehr and his associates used two sealed jars of water, praying over one and ignoring the other. Then they used each to water separate but equal sets of seeds planted under identical conditions. "In 2 weeks," it was reported, "the prayed-over water had produced seven seedlings, the ordinary water only three." Later experiments apparently eliminated the vehicle and directed the prayer at the seeds and plants themselves, but the efficacy of water as a vehicle for transmitting the power of prayer to plants was apparently proved.

All of which may suggest that if you're counting on a water binge to cure anything serious, you'd better not pray over it too hard or you might find yourself pushing up daisies.

Harold E. Babbitt, professor emeritus at the University of Illinois and presently visiting professor of civil engineering at the University of Missouri, will serve as director of the sanitary engineering program at Iowa State University during the absence of Prof. E. Robert Baumann. The latter will spend the 1959–60 academic year studying in England on a National Science Foundation fellowship.

Bogert & Childs, consulting engineers, New York, have announced the retirement of Fred S. Childs. The firm will operate in the future under the name "Clinton Bogert Engineers."

Henry M. Gerber, president of Louisville (Ky.) Water Co., died May 14, 1959, at the age of 74. Born near Cannelton, Ind., he came to Louisville in 1905 and entered the furniture business. In 1937, the year in which his store was destroyed by flood, he became president of the water company. During his tenure the utility's output rose from 16 bil gal to 29 bil gal. He was particularly proud of the fact that not only did the system pay for this expansion out of revenue, but that more than $20,000,000 in dividends was turned over to the city as well.

Mr. Gerber, who had represented his company in AWWA since 1938, was serving as chairman of the Kentucky-Tennessee Section at the time of his death.

Wesley E. Mahan, superintendent of pipelines for the Fort Smith, Ark., water department, was found dead under tragic circumstances May 21, 1959. He was 46. Mahan had disappeared on Apr. 18. Though his car was discovered the next day in the vicinity of Arkoma, Okla., his body was not found until nearly a month later, on an island in the Arkansas River near Fort Smith. The cause of death was not immediately determined.

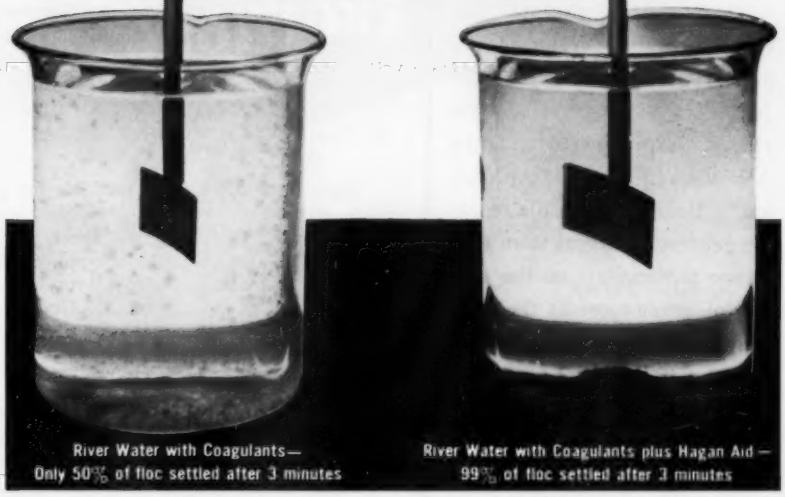
Employment Information

Classified ads will be accepted only for "Positions Available" or "Position Wanted." Rate: $1.50 per line (minimum $5.00), payable before publication. Deadline for ad copy: first of month prior to month of publication desired. To place ad, obtain "Classified Ad Authorization Form" from: Classified Ad Dept., Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

Positions Available

HYDRAULIC ENGINEER. Degree in Civil Engineering with minimum of five years' experience in Hydrological Engineering. To conduct surface water studies throughout state. Liberal state employee benefits. Apply or write: Division of Personnel, Room 304, State Finance Building, Capitol Square, Richmond, Virginia.

Faster coagulation... larger floc... increased throughput... with HAGAN COAGULANT AIDS


River Water with Coagulants—
Only 50% of floc settled after 3 minutes
River Water with Coagulants plus Hagan Aid—
99% of floc settled after 3 minutes

Scientifically formulated Hagan Coagulant Aids 2, 7, 11 and 18 are the most effective means of improving coagulation in all types of clarification equipment, and are completely safe for drinking waters.

Supplied in free-flowing granular form, they are easy to use since they may be dry fed or readily prepared as slurries. While Aid No. 2 is a pure polyelectrolyte, Aids 7, 11 and 18 are intimate blends of: (1) polyelectrolyte to promote rapid floc growth and (2) processed clays to serve as nuclei around which floc forms readily. They also provide weight to increase the settling rate of the floc. One of the four Hagan Coagulant Aids will meet your specific water condition.

In over three years of use in municipal water clarification, Hagan Coagulant Aids have increased clarifier throughput rates, reduced floc carryover, simplified clarifier operation, improved color removal and even reduced overall chemical treatment costs in many plants.

We will be glad to conduct coagulation studies to determine which of the several Hagan Coagulant Aids is best for your particular operation. These tests will be confirmed at the plant site by an experienced Calgon engineer. For information, write:

CALGON COMPANY
DIVISION OF HAGAN CHEMICALS & CONTROLS, INC.
HAGAN BUILDING, PITTSBURGH 30, PA.
In Canada: Hagan Corporation (Canada) Limited, Toronto

AWWA WATER RATES MANUAL

The report of the AWWA Committee on Water Rates published in the March 1954 JOURNAL is now available in reprint form as part of the AWWA "Water Rates Manual." Bound in with the report are generous excerpts from such classic publications on the subject of water rates as the Metcalf, Kuichling, and Hawley paper of 1911 on fire protection charges and the reports of NEWWA and AWWA committees chairmanned by Allen Hazen, as well as a table of cost indexes, an outline for allocation of plant and expenses, and other valuable supplementary material.

61 pages **$1.25**

($1.00 to members paying in advance)

American Water Works Association

2 Park Ave., New York 16, N. Y.

Service Lines

Pump controls, as well as starters and contactors for motors, are among the items discussed in a 12-page booklet titled "Industrial and Motor Controls." The catalog, which is illustrated with photographs and detailed diagrams, is available by writing B/W Controller Corp., 2211 E. Maple Rd., Birmingham, Mich.

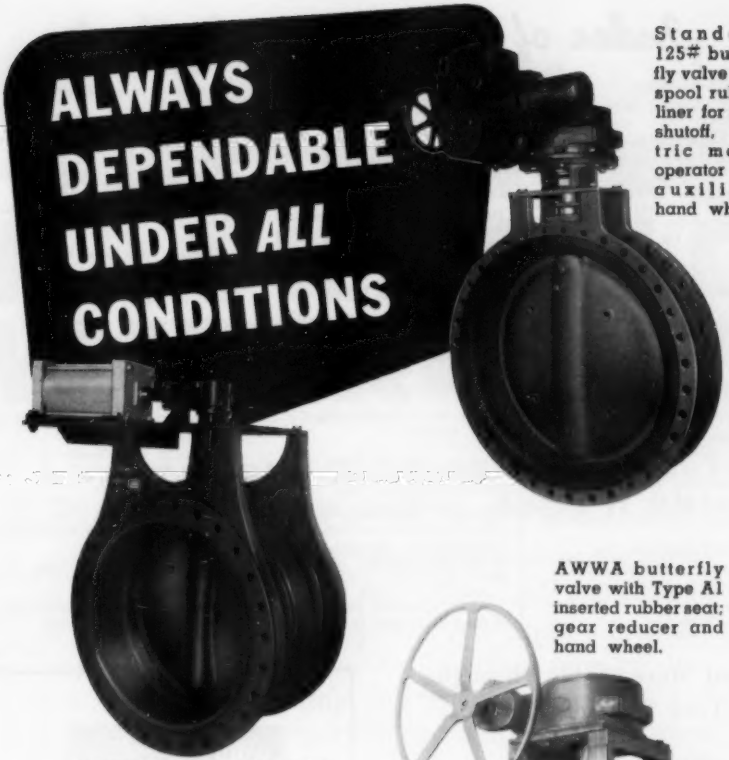
Sight flow indicators, available for ¼–2-in. pipe, are completely described and diagrammed in a new data sheet. The information, which includes applications for high- or low-temperature service, is available by requesting Data Unit No. 350 from Jerguson Gage & Valve Co., 80 Adams St., Burlington, Mass.

Automatic chlorine feeders, designed for uniform and accurate chlorination at all flows, are described and illustrated in a 4-page bulletin. Information is included on various applications of this equipment in combination with other devices. Bulletin 840.20A-2 may be obtained from B-I-F Industries, Inc., 345 Harris Ave., Providence 1, R.I.

Well formation testing is one of the services covered in a new 130-page catalog. The colorfully illustrated book describes in detail, with many diagrams, products and services pertaining to wells. The 1959 Sales and Service Catalog is available from Halliburton Oil Well Cementing Co., Duncan, Okla.

Concrete products are described, with data on application and estimating of requirements, in a 6-page "Product Data Guide." This publication is available by writing for Bulletin X-5A to The Master Builders Co., Cleveland 3, Ohio.

ALWAYS DEPENDABLE UNDER *ALL* CONDITIONS



Standard 125# butterfly valve with spool rubber liner for tight shutoff, electric motor operator and auxiliary hand wheel.

AWWA butterfly valve with spool rubber liner for tight shutoff; air cylinder operator.

AWWA butterfly valve with Type A1 inserted rubber seat; gear reducer and hand wheel.

Rockwell valves for water control and shutoff service assure the MOST in reliability: minimum restriction to flow; minimum pressure drop; less installation space and maintenance. Bulletins 581 and 582 tell why.

ROCKWELL SINCE 1888 BUILT

BUTTERFLY VALVES

W. S. ROCKWELL COMPANY

2609 Eliot Street, Fairfield, Conn.

Index of Advertisers' Products

Activated Carbon:
Industrial Chemical Sales Div.
Permutit Co.

Activated Silica Generators:
B-I-F Industries, Inc.—Omega
Wallace & Tiernan Inc.

Aerators (Air Diffusers):
American Well Works
Carborundum Co.
General Filter Co.
Permutit Co.
Walker Process Equipment, Inc.

Air Compressors:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Worthington Corp.

Alum (Sulfate of Alumina):
American Cyanamid Co., Process Chemicals Dept.
General Chemical Div., Allied Chemical Corp.

Ammonia, Anhydrous:
General Chemical Div., Allied Chemical Corp.
Jones Chemicals, Inc.

Ammoniators:
B-I-F Industries, Inc.—Proportioneers
Wallace & Tiernan Co., Inc.

Ammonium Silicofluoride:
American Agricultural Chemical Co.

Brass Goods:
American Brass Co.
Hays Mfg. Co.
Mueller Co.

Brine-Making Equipment:
International Salt Co., Inc.

Calcium Hypochlorite:
Jones Chemicals, Inc.
Olin Mathieson Chemical Corp.

Carbon Dioxide Generators:
Walker Process Equipment, Inc.

Cathodic Protection:
Electro Rust-Proofing Corp.

Cement Mortar Lining:
Centriline Corp.
Halliburton Oil Well Cementing Co.
Southern Pipe & Casing Co.

Chemical Feed Apparatus:
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Graver Water Conditioning Co.
F. B. Leopold Co.
Permutit Co.
Precision Chemical Pump Corp.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Chemists and Engineers:
(See Professional Services)

Chlorination Equipment:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioneers
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Chlorine Comparators:
Klett Mfg. Co.
Wallace & Tiernan Inc.

Chlorine, Liquid:
Jones Chemicals, Inc.
Olin Mathieson Chemical Corp.
Wallace & Tiernan Inc.

Clamps and Sleeves, Pipe:
James B. Clow & Sons
Dresser Mfg. Div.
Ludlow Valve Mfg. Co., Inc.
Mueller Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.

Clamps, Bell Joint:
James B. Clow & Sons
Dresser Mfg. Div.

Clamps, Pipe Repair:
James B. Clow & Sons
Dresser Mfg. Div.
Trinity Valley Iron & Steel Co.

Clarifiers:
American Well Works
Chain Belt Co.
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
Permutit Co.
Walker Process Equipment, Inc.

Coagulant Aids:
Hagan Chemicals & Controls, Inc.
National Aluminate Corp.

Need More Water Through Your Existing Plant?

Specify—

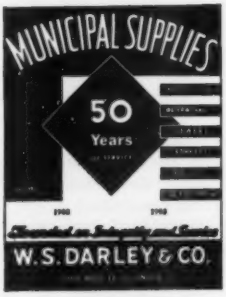
WALKING BEAM FLOCCULATION EQUIPMENT

Because:

1. Easily adapts to existing basins of different sizes.
2. Less retention time required to form tough, stable floc.
3. No underwater maintenance.
4. No dry well construction.

Write TODAY for information.

STUART CORPORATION
516 N. Charles St., Baltimore 1, Md.



WRITE TODAY
For
100 PAGE CATALOG

W. S. DARLEY & CO. Chicago 12

PACKAGED WATERLINES

Lower costs! Eliminate worries! One purchase order does it all!

NOW—A REVOLUTIONARY NEW LOW-COST CONCEPT IN PIPE BUYING

Southern Pipe *Packaged Waterlines* offer you a brand new way to save money, cut red tape, eliminate worries. One order does it all—from pipe production, lining and coating, to trenchsite delivery. You buy one complete waterline package, delivered when you need it.

SOUTHERN PIPE *PACKAGED WATERLINES* GIVE YOU:

(1) pipe produced to your exacting specifications,
(2) from steel coil in our own pipe mill,
(3) cut precisely with NO random lengths,
(4) lined and coated at our plant,
(5) warehoused, if necessary, until you need it, and
(6) delivered to your trenchsite ready for placing in trench.

Packaged Waterlines from our warehouse stock of standard sizes are also available for immediate delivery.

Write for PACKAGED WATERLINES brochure today.

© 1959—So. Pipe • Div. of U.S. Industries, Inc.

USI Southern Pipe

DIVISION OF U.S. INDUSTRIES, INC.

P.O. BOX C • AZUSA, CALIFORNIA • COmberland 3-7111 - EDgewood 7-1221

SP-25-59

Condensers:
Allis-Chalmers Mfg. Co.
United States Pipe & Foundry Co.
Worthington Corp.

Contractors, Water Supply:
Layne & Bowler, Inc.

Controllers, Liquid Level, Rate of Flow:
B-I-F Industries, Inc.—Builders
Foxboro Co.
General Filter Co.
Simplex Valve & Meter Co.
Sparling Meter Co.

Copper Sheets:
American Brass Co.

Copper Sulfate:
General Chemical Div., Allied Chemical Corp.
Tennessee Corp.

Corrosion Control:
Calgon Co.
National Aluminate Corp.
Philadelphia Quartz Co.

Couplings, Flexible:
DeLaval Steam Turbine Co.
Dresser Mfg. Div.
E. H. Wachs Co.

Covers, Vault:
Ford Meter Box Co.
E. H. Wachs Co.

Desalinization Plants:
Emhart Mfg. Co., Maxim Div.

Diaphragms, Pump:
Dorr-Oliver Inc.

Engineers and Chemists:
(See Professional Services)

Evaporating Equipment:
Emhart Mfg. Co., Maxim Div.

Feedwater Treatment:
B-I-F Industries, Inc.—Proportioneers
Calgon Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
National Aluminate Corp.
Permutit Co.

Ferric Sulfate:
Tennessee Corp.

Filter Materials:
Anthracite Equipment Corp.
Carborundum Co.
Dicalite Div.
General Filter Co.
Johns-Manville Corp.
Monterey Sand Co.
Northern Gravel Co.
Permutit Co.
Stuart Corp.

Filters, incl. Feedwater:
B-I-F Industries, Inc.—Proportioneers
Dorr-Oliver Inc.
Graver Water Conditioning Co.
Permutit Co.
Roberts Filter Mfg. Co.
Ross Valve Mfg. Co.

Filtration Plant Equipment:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
Chain Belt Co.
Cochrane Corp.
Filtration Equipment Corp.
General Filter Co.
Golden-Anderson Valve Specialty Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.
Roberts Filter Mfg. Co.
Simplex Valve & Meter Co.
Stuart Corp.
Wallace & Tiernan Inc.

Fittings, Copper Pipe:
Dresser Mfg. Div.
Hays Mfg. Co.
Mueller Co.

Fittings, Tees, Ells, etc.:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Dresser Mfg. Div.
M & H Valve & Fittings Co.
Morgan Steel Products, Inc.
Southern Pipe & Casing Co.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Flocculating Equipment:
Chain Belt Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
F. B. Leopold Co.
Permutit Co.
Stuart Corp.

Fluoride Chemicals:
American Agricultural Chemical Co.
Olin Mathieson Chemical Corp.
Tennessee Corp.

Fluoride Feeders:
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Wallace & Tiernan Co., Inc.

Furnaces:
Jos. G. Pollard Co., Inc.

Gages, Liquid Level:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.
Sparling Meter Co.
Wallace & Tiernan Inc.

Gages, Loss of Head, Pressure of Vacuum, Rate of Flow, Sand Expansion:
B-I-F Industries, Inc.—Builders
Foxboro Co.
Jos. G. Pollard Co., Inc.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Gasholders:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Gaskets, Rubber Packing:
James B. Clow & Sons
Johns-Manville Corp.

Gates, Shear and Sluice:
Armco Drainage & Metal Products, Inc.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Mueller Co.
R. D. Wood Co.

Gears, Speed Reducing:
DeLaval Steam Turbine Co.
Worthington Corp.

Glass Standards—Colorimetric Analysis Equipment:
Klett Mfg. Co.
Wallace & Tiernan Inc.

Goosenecks (with or without Corporation Stops):
James B. Clow & Sons
Mueller Co.
Southern Pipe & Casing Co.

Hydrants:
James B. Clow & Sons
Darling Valve & Mfg. Co.
M. Greenberg's Sons
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Hydrogen Ion Equipment:
Photovolt Corp.
Wallace & Tiernan Inc.

Hypochlorite; see Calcium Hypochlorite; Sodium Hypochlorite

Ion Exchange Materials:
Chemical Process Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
National Aluminate Corp.
Permutit Co.
Roberts Filter Mfg. Co.
Rohm & Haas Co.

Iron, Pig:
Woodward Iron Co.

Iron Removal Plants:
American Well Works
Chain Belt Co.
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Jointing Materials:
Johns-Manville Corp.
Keasbey & Mattison Co.
Leadite Co., Inc.

Joints, Mechanical, Pipe:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Dresser Mfg. Div.
Southern Pipe & Casing Co.
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Leak Detectors:
Aqua Survey & Instrument Co.
Jos. G. Pollard Co., Inc.

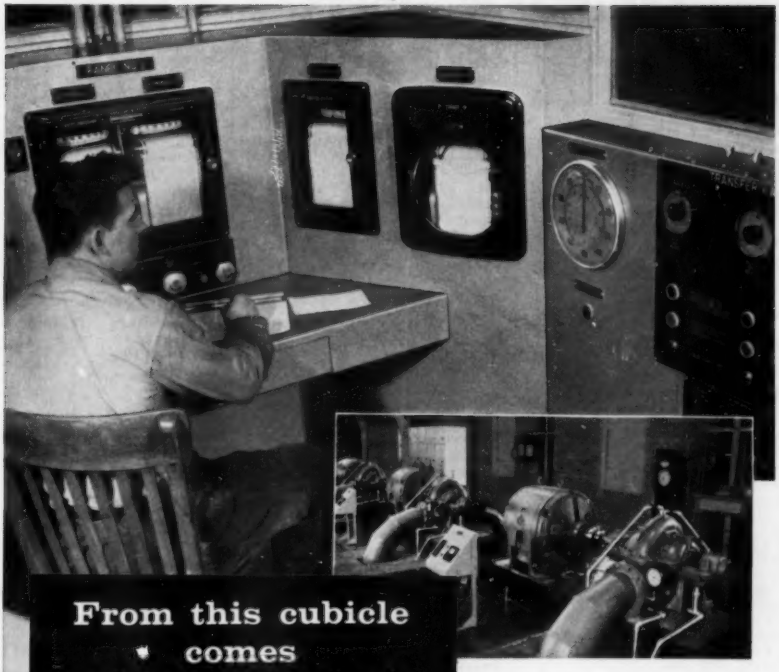
Lime Slakers and Feeders:
B-I-F Industries, Inc.—Omega
Dorr-Oliver Inc.
General Filter Co.
Infilco Inc.
Permutit Co.
Wallace & Tiernan Inc.

Locators, Pipe & Valve Box:
Aqua Survey & Instrument Co.
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Magnetic Dipping Needles:
Aqua Survey & Instrument Co.
W. S. Darley & Co.

Meter Boxes:
Ford Meter Box Co.
Pittsburgh Equitable Meter Div.

Meter Couplings and Yokes:
Badger Meter Mfg. Co.
Dresser Mfg. Div.



From this cubicle comes advance proof of pump performance

Typical A-C pumping installation is this one in the District No. 2 Water Works at Pueblo, Colorado. Motors and control are also supplied by Allis-Chalmers.

This master control room of Allis-Chalmers pump test floor is far removed from public works installations. Yet engineers working here know exactly what your needs are — and which Allis-Chalmers pump will best do the job.

Performance testing like this is only one reason why A-C is recognized as a full-line leader in meeting the pump needs of municipals. "Teamed" motors and control; customized standardization of parts and materials; engineering assistance and nationwide service are others.

Whatever your requirements in centrifugal pumps — from the smallest to 250,000-gpm giants — contact your A-C representative or distributor. *Or write to Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.*

ALLIS-CHALMERS A-5981-PW

Ford Meter Box Co.
Gamon Meter Div., Worthington Corp.
Hays Mfg. Co.
Hersey Mfg. Co.
Mueller Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Filtration Plant, Pumping Station, Transmission Line:
B-I-F Industries, Inc.—Builders
Foster Eng. Co.
Simplex Valve & Meter Co.
Sparling Meter Co.

Meters, Industrial, Commercial:
Badger Meter Mfg. Co.
B-I-F Industries, Inc.—Builders
Buffalo Meter Co.
Burgess-Manning Co., Penn Instruments Div.
Calmet Meter Div., Worthington Corp.
Gamon Meter Div., Worthington Corp.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
Sparling Meter Co.

Mixing Equipment:
Chain Belt Co.
General Filter Co.
F. B. Leopold Co.

Paints:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.
Wilbur & Williams Co., Inc.

Pipe, Asbestos-Cement:
Johns-Manville Corp.
Keasbey & Mattison Co.

Pipe, Brass:
American Brass Co.

Pipe, Cast Iron (and Fittings):
Alabama Pipe Co.
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Southern Pipe & Casing Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
American Concrete Pressure Pipe Assn.
American Pipe & Construction Co.
Lock Joint Pipe Co.
Vulcan Materials Co.

Pipe, Copper:
American Brass Co.

Pipe, Plastic:
Morgan Steel Products, Inc.
Orangeburg Mfg. Co.

Pipe, Steel:
Armco Drainage & Metal Products, Inc.
Bethlehem Steel Co.
Morgan Steel Products, Inc.
Southern Pipe & Casing Co.

Pipe Cleaning Services:
Centriline Corp.
National Water Main Cleaning Co.

Pipe Coatings and Linings:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.
Reilly Tar & Chemical Corp.
Southern Pipe & Casing Co.

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Pilot Mfg. Co.
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.
E. H. Wachs Co.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators; see Locators, Pipe

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
B-I-F Industries, Inc.—Proportioneers
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.
Peerless Pump Div.

Pumps, Diaphragm:
Dorr-Oliver Inc.
W. S. Rockwell Co.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Peerless Pump Div.
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.
Sparling Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves: see Clamps

Sleeves and Valves, Tapping:
James B. Clow & Sons
Ludlow Valve Mfg. Co.
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

Sludge Blanket Equipment:
Cochrane Corp.
General Filter Co.
Graver Water Conditioning Co.
Infilco Inc.
Permutit Co.

Sodium Aluminate:
National Aluminate Corp.

Sodium Chloride:
International Salt Co., Inc.

Sodium Fluoride:
American Agricultural Chemical Co.

Sodium Hexametaphosphate:
Calgon Co.

Sodium Hypochlorite:
Jones Chemicals, Inc.
Wallace & Tiernan Inc.

Sodium Silicate:
Philadelphia Quartz Co.

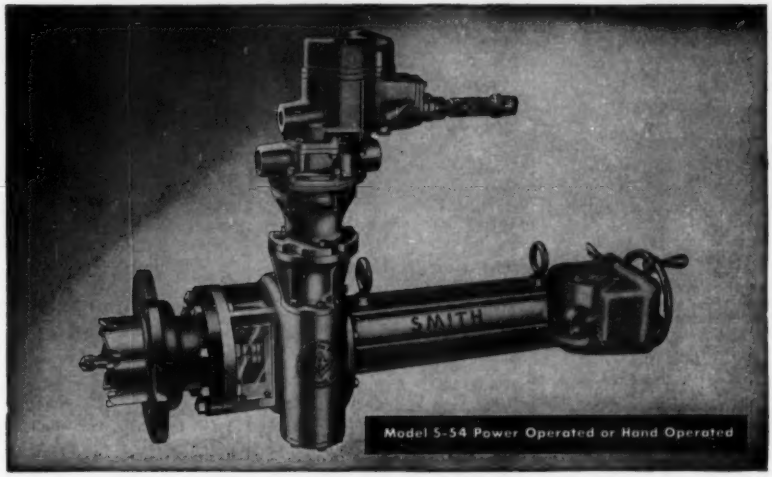
Sodium Silicofluoride:
American Agricultural Chemical Co.
Tennessee Corp.

Softeners:
Cochrane Corp.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
Calgon Co.
General Filter Co.
International Salt Co., Inc.
National Aluminate Corp.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.

SMITH TAPPING MACHINES FOR TAPS 2" THRU 12" INCLUSIVE



Model S-54 Power Operated or Hand Operated

The Smith S-54 Tapping Machine is the most modern, efficient and economical machine available. S-54 Machines are produced with either 25" or 37" travel. The Machine is used with Tapping Sleeves, Hat Flanges, Saddles and Tapping Valves to make 2" through 12" connections under pressure to Cast Iron, Cement-Asbestos, Steel and Reinforced Concrete Pressure pipe. Features: 1. Positive automatic feed insures correct drilling and tapping rate. 2. Travel is automatically terminated when tap is completed—cutter and shaft cannot overtravel. 3. Telescopic shaft reduces overall length. 4. Mechanism is housed in heat treated Aluminum Case filled with lubricant. 5. Stuffing Box and Packing Gland is accessible without disassembling machine. Line pressure cannot enter machine case. 6. Extra large diameter telescopic shaft adds strength and rigidity. Timken radial-thrust bearings maintain alignment, reduce friction and wear. 7. Worm gearing operates in lubricant, torque is reduced to the minimum. 8. Cutters have replaceable Flat and Semi-V alternate teeth of High Speed Steel or Tungsten Carbide. 9. Flexibility: Hand Operated Machines can be converted to Power Operation by interchanging worm gearing. Bulletin T54 sent on request.

53

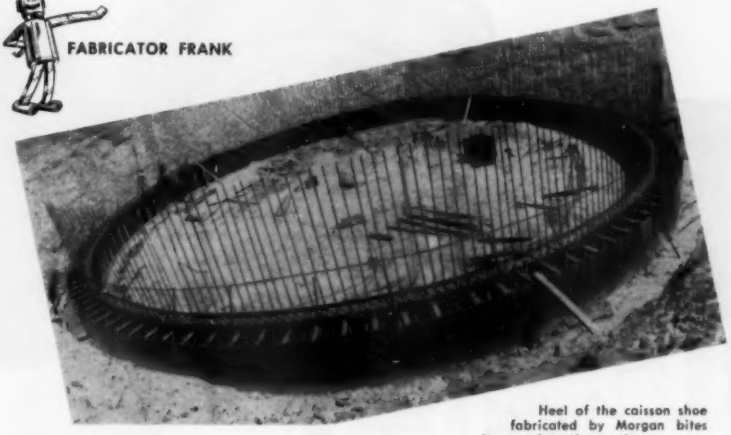
THE A.P. SMITH MFG. CO.
EAST ORANGE NEW JERSEY

Hammond Iron Works
Pittsburgh-Des Moines Steel Co.
Steel Plate Construction:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.
Stops, Curb and Corporation:
Ford Meter Box Co.
Hays Mfg. Co.
Mueller Co.
Storage Tanks: see Tanks
Strainers, Suction:
James B. Clow & Sons
R. D. Wood Co.
Surface Wash Equipment:
Golden-Anderson Valve Specialty Co.
Permutit Co.
Swimming Pool Sterilization:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Omega
B-I-F Industries, Inc.—Proportioneers
Wallace & Tiernan Inc.
Tank Painting and Repair:
Koppers Co., Inc.
Taylor Iron Works
Wilbur & Williams Co., Inc.
Tanks, Prestressed Concrete:
Preload Co., Inc.
Tanks, Steel:
Bethlehem Steel Co.
Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Morgan Steel Products, Inc.
Pittsburgh-Des Moines Steel Co.
Taylor Iron Works
Tapping-Drilling Machines:
Hays Mfg. Co.
Mueller Co.
A. P. Smith Mfg. Co.
Tapping Machines, Corp.:
Hays Mfg. Co.
Mueller Co.
Taste and Odor Removal:
B-I-F Industries, Inc.—Builders
B-I-F Industries, Inc.—Proportioneers
General Filter Co.
Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Permutit Co.
Wallace & Tiernan Inc.
Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):
Wallace & Tiernan Inc.
Turbines, Steam:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
Turbines, Water:
DeLaval Steam Turbine Co.
Valve Boxes:
James B. Clow & Sons
Ford Meter Box Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
A. P. Smith Mfg. Co.
Trinity Valley Iron & Steel Co.
R. D. Wood Co.
Valve-Inserting Machines:
Mueller Co.
A. P. Smith Mfg. Co.

Valves, Altitude:
Allis-Chalmers Mfg. Co., Hydraulic Div.
Golden-Anderson Valve Specialty Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co., Inc.
Valves, Butterfly, Check, Flap, Foot, Hose, Mud and Plug:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
Chapman Valve Mfg. Co.
James B. Clow & Sons
DeZurik Corp.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
W. S. Rockwell Co.
R. D. Wood Co.
Valves, Detector Check:
Hersey Mfg. Co.
Valves, Electrically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
Valves, Float:
James B. Clow & Sons
Golden-Anderson Valve Specialty Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co., Inc.
Valves, Gate:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.
Valves, Hydraulically Operated:
Allis-Chalmers Mfg. Co., Hydraulic Div.
B-I-F Industries, Inc.—Builders
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
F. B. Leopold Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.

Valves, Large Diameter:
Allis-Chalmers Mfg. Co., Hydraulic Div.
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
Pelton Div., Baldwin-Lima-Hamilton
Henry Pratt Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.
Valves, Regulating:
Allis-Chalmers Mfg. Co., Hydraulic Div.
DeZurik Corp.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co.
Valves, Swing Check:
Chapman Valve Mfg. Co.
James B. Clow & Sons
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Mueller Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
R. D. Wood Co.
Venturi Tubes:
B-I-F Industries, Inc.—Builders
Simplex Valve & Meter Co.
Waterproofing:
Inertol Co., Inc.
Koppers Co., Inc.
Plastics & Coal Chemicals Div., Allied Chemical Corp.
Water Softening Plants; see Softeners
Water Supply Contractors:
Layne & Bowler, Inc.
Water Testing Apparatus:
LaMotte Chem. Products Co.
Wallace & Tiernan Inc.
Water Treatment Plants:
American Well Works
Chain Belt Co.
Chicago Bridge & Iron Co.
Dorr-Oliver Inc.
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Pittsburgh-Des Moines Steel Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.
Wallace & Tiernan Inc.
Well Drilling Contractors:
Layne & Bowler, Inc.
Well Reconditioning and Formation Testing:
Halliburton Oil Well Cementing Co.
Layne & Bowler, Inc.
Wrenches, Ratchet:
Dresser Mfg. Div.
Zeolite: see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1957 AWWA Directory.



Heel of the caisson shoe fabricated by Morgan bites its way into the earth.

GIGANTIC PUMPING STATION PROVES MORGAN VERSATILITY

Through Morgan Know-How, Dollar Savings are Proven Every Time!

A caisson shoe fabricated by Morgan served as both the base and the constructing element of a well with five foot thick concrete walls and a diameter of 110 feet!

The 100-ton caisson shoe forms a double ring with the outside diameter of 110 feet. Fabricated by Morgan of ⅝" thick steel plate, the double walls are five feet apart at the top, and taper to nine inches at the bottom, or cutting edge.

Concrete poured in between the walls through top receiving sections, forced the tapered shoe into the earth to a depth of over 100 feet; and simultaneously filled the hole which was being made to form the walls of the well.

Morgan's caisson shoe now rests over 100 feet below the ground on a rock base. The well it constructed serves as an important link betwen the Ohio River and Cincinnati pumping and filtering stations. The versatility and know-how of the Morgan engineer-fabricating team once again has resulted in a difficult job problem being solved efficiently and quickly.

SEND FOR YOUR FREE BROCHURE ON FABRICATING METHODS . . .

IT WILL SAVE YOU MONEY!

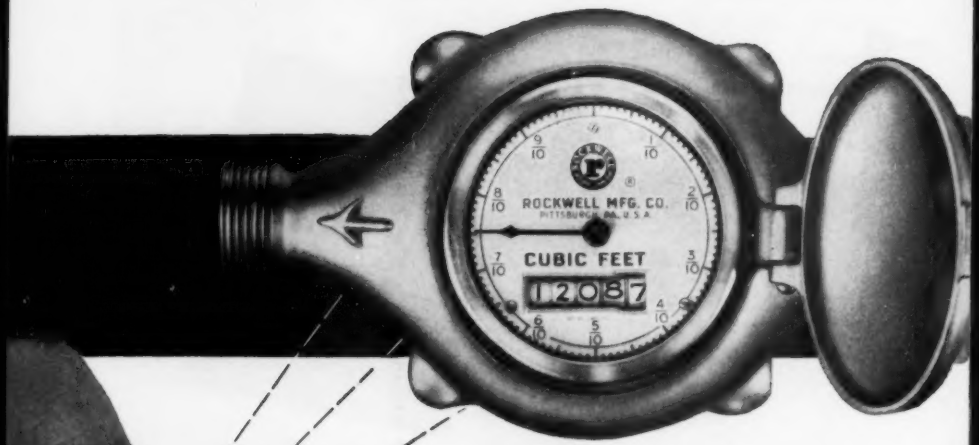
Morgan Steel Products, Inc.

CUSTOM STEEL FABRICATORS

Working in all types of ferrous alloy . . . ODD AND LARGE SIZE PIPE . . . BINS . . . TANKS . . . CHUTES . . . SMOKESTACKS . . . HOPPERS . . . BREECHINGS . . .

6700 MORGAN AVENUE • CLEVELAND 27, OHIO • Michigan 1-2000

You can't miss!



There's Visibility Unlimited in

ROCKWELL

Sealed Register

METERS

You can't miss getting a quick, accurate reading from any Rockwell Sealed Register meter. A row of bold figures looks you straight in the eye through a window that never becomes dirty or fogged. In fact you can even run this meter under water. That's because the register and all the reduction gears are *hermetically sealed* to stay clean, dry and free of condensation.

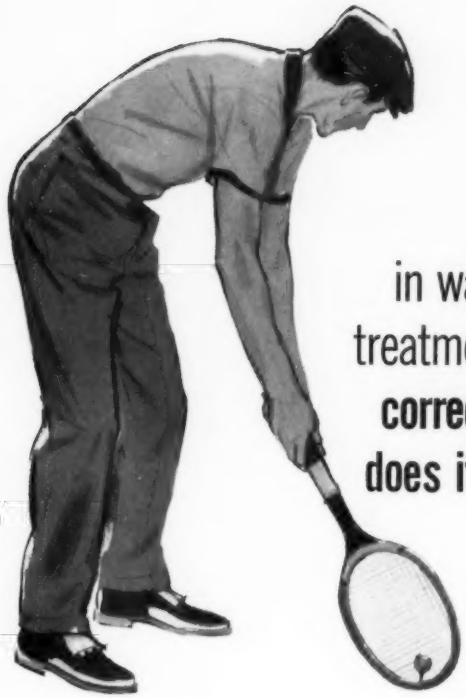
With Rockwell Sealed Register meters you'll never again be called upon to service leaky or bound stuffing boxes *for there are none.* A powerful magnetic drive couples the measuring chamber to the register without mechanical linkage or seals. And in this revolutionary meter there are only two moving parts operating in water. Truly, the Rockwell Sealed Register meter is the least vulnerable to wear or corrosion—the smoothest running and most accurate. Write for catalog. Rockwell Manufacturing Co., Pittsburgh 8, Pa.

Now available in both 5/4" and full 3/4" sizes

SEALED REGISTER METERS

another fine product by

ROCKWELL



in water treatment, too... correct equipment does it better!

Golf, anyone? Or does the gentleman think he's playing tennis? Whatever the game, best results come from using the right equipment. • That goes for water treatment, too. Because no two water treatment problems are exactly alike, Dorr-Oliver offers a variety of equipment units and methods that provides maximum scope in designing to meet individual needs. The efficiency of this equipment is being demonstrated in thousands of modern plants throughout the world. Every day, over 8½ billion gallons of water are treated by Dorr-Oliver equipment. • If you would like more information on the complete line of Dorr-Oliver water treatment, write to Dorr-Oliver Incorporated, Stamford, Connecticut, for a copy of Bulletin 9141.

DORR-OLIVER
INCORPORATED
WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U.S.A.

DORR PRE-SEDIMENTATION THICKENERS • DORR FLASH MIXER • DORRCO SLAKER • DORRCO FLOCCULATOR • DORR SIFEED CLARIFIER • DORRCO SQUAREX CLARIFIER • DORRCO MONORAKE • DORRCO CLARIFLOCCULATOR • DORRCO HYDROTREATOR • DORRCO ALDRICH PERI-FILTER SYSTEM • DORR SLUDGE THICKENER • DORRCO HYDRO-SOFTENER • DORRCLONE DESANDING SYSTEM • DORRCO SLUDGE PUMPS

LEADITE

Trade Mark Registered U. S. Pat. Office

Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains MUST BE GOOD,—MUST BE DEPENDABLE,—and that is just why so many Engineers, Water Works Men and Contractors aim to PLAY ABSOLUTELY SAFE, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%

THE LEADITE COMPANY
Girard Trust Co. Bldg. Philadelphia, Pa.

No Caulking